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ADAPTATION TO AQUATIC, ARBOREAL, FOS-SORIAL AND CURSORIAL HABITS IN MAMMALS.[1]

I. AQUATIC ADAPTATIONS.

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THERE seems to be no doubt whatever that all mammals were originally terrestrial animals. However, either the abundance of food occurring in the water or the competition existing on the land has from time to time led or driven many species to an

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[1] In the *American Naturalist* of May, 1902, I published an article entitled "The Law of Adaptive Radiation," a development of the idea of divergent evolution as applied to the larger and smaller groups of mammals. There was considered first, *general adaptive radiation* including the radiation of marsupials and the six independent radiations of the Placentalia, second the law of *local adaptive radiation* and finally the bearing of adaptive radiation on Cuvier's *law of correlation.* Pursuing this general idea of adaptive radiation it appeared desirable to reëxamine and compare the mammals as to the adaptations of different kinds which arise independently in different groups, in other words the *parallel adaptations.*

A number of advanced students of the evolution of mammals undertook this comparison and the results were so interesting and in many cases so novel that they appeared worthy of publication in the *American Naturalist.* They form the basis of the three or four articles which the *Naturalist* will publish successively.

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aquatic life. The following list, though making no pretensions to completeness, will serve to indicate how great and varied a number of forms have become, either from choice or necessity, more or less aquatic.

     Cetacea, the entire order.

     Sirenia, the entire order.

     Carnivora,

          Pinnipedia, the entire suborder.

          Fissipedia,

               Lutra, the various species of otters.

               Enhydris (Latax), the sea-otter.

               Putorius, the mink and sumpfotter.

     Rodentia, many scattered examples, as —

               Myocastor (Myopotamus).

               Hydrochœrus, the capybara.

               Hydromys, the Australian water-rat.

               Hydrochilus.

               Microtus (Arvicola) the water-vole.

               Ichthyomys.

               Castor, the beavers.

               Fiber and Neofiber, the muskrats.

     Insectivora, many scattered examples, as —

               Myogale, the desman.

               Crossopus (Sorex) the water-shrew.

               Neosorex, the American water-shrew

               Chimarrogale.

               Nectogale.

               Potamogale.

               Limnogale.

     Ungulata,

          Artiodactyla,

               Hippopotamus.

     Marsupiala,

               Chironectes, the water-opossum.

     Monotremata,

               Ornithorhynchus.

Besides these there might be mentioned among extinct forms the Zeuglodontidæ, thoroughly aquatic animals doubtfully related

to the Cetacea, or according to some authors, to the Pinnipedia ; the oreodont Merycochœrus, probably semi-aquatic, the creodont Patriofelis, a possible ancestor of the Pinnipedia, and the extinct rhinoceros, *Metamynodon planifrons* Scott and Osborn, which, though related to modern species which are not aquatic, had the shorter nasals, more dorsal external nares and more dorsally curved ribs which mark many aquatic forms, as will be shown later.

That many forms have but recently become aquatic is certain in such as have undergone little or no modification in structure, while others must have assumed aquatic life in very remote times if the amount of the adaptation to the environment is any criterion.   Kükenthal points out that the amount of adaptation depends upon the length of time during which the influence of the water has been operating and upon the amount of connection retained with the land, and that we can assign the relationships of aquatic mammals with certainty in proportion to the time that has elapsed since they were separated from their terrestrial relatives.   For example, we know definitely the relationships of the forms that have recently taken up the aquatic habit, such as the otters, muskrats, etc., of the Pinnipedia we know that they are Carnivora, of the Sirenia we know almost nothing (according to various authors they have been held to show relationships with the Ungulata, which view the evidence largely favors, the Cetacea, or to form an entirely distinct stem.), and as to the Cetacea we are absolutely in the dark.   Kükenthal even maintains that the latter group is diphyletic from quite different sources and that the supposed relationships between the Odontoceti and the Mystacoceti are merely parallelisms due to similarity of environment.   The reason for this is to be found in the profound modification resulting from life in the water which affects internal as well as external structures and leads to parallelisms in many structures in forms not genetically related.

For convenience in treatment, the various adaptations may for the most part be roughly classified in three groups as follows : — I. Adaptations connected with the general body form including those of the head, trunk and tail regions.   II. Those affecting the limbs.   III. Those affecting the integument.

I.   The tendency of the body to take on a "fish-like" form is too well known to need any discussion, as it goes without saying that such a form is best adapted to progress in the water. It is most marked in such animals as are most aquatic, as the Cetacea, Sirenia and Pinnipedia, and to a less extent in other forms as Enhydris, Potamogale, etc.   The anterior part of the body tends to become more rigid and concentrated, especially in the cervical region, while the posterior part of the body becomes more mobile for purposes of propulsion.

In the head there is found in the Cetacea and the extinct zeuglodonts a lengthening of the face with a shortening of the cranium.   In the most extreme cases the head is nearly one third the length of the body.   In the Sirenia the face is some-what elongate, but not excessively so, while in the Pinnipedia it is never very elongate and may be quite short, while the cranium is broad and flat.   The length of the head is conditioned so largely by the length of the jaws that it would seem that its shape is not a result merely of life in the water, so much as of adaptation to certain kinds of aquatic food.   The secondary simplification of the teeth which takes place in all truly aquatic mammals must also be connected with food conditions.   In the Mystacoceti the teeth are never functional but are present only in the embryo and are absorbed before birth and replaced by whalebone.   As the food consists of very minute forms the adaptation is evident.   In the Odontoceti or toothed whales the teeth are purely raptorial in character, simple and fang-like and often retroverted, and admirably adapted for the capture of the food, which in most cases consists of cephalopods, crustaceans and fishes.   The number of teeth may be greatly increased as in Globiocephalus where the total number may be over 100, and even twice that number may be found in Delphinus and Inia, or the number may be greatly reduced as in Monodon and Ziphius, or the teeth may be vestigial as in Hyperoodon.   In the extinct zeuglodonts the teeth had not become so simplified, as they still possessed two roots and a crenulated crown.   This "zeuglo-dont" condition of the teeth is found at the present time in the majority of the Pinnipedia.   In the herbivorous Sirenia the teeth when present are of the bilophodont type, undoubtedly adaptive

to the food, which consists of aquatic plants. In the recently extinct genus Rhytina the teeth are absent and are replaced by horny plates. In the manatee they are secondarily increased in number. Along with the simplification of the dentition is found occurring a great simplification of the jaws, particularly the lower which tends toward the loss of all prominences for the attachment of muscles, so that in the Cetacea the coronoid process is often greatly reduced and the angle as well. The articulation with the squamosal becomes loose and simplified, and the symphysis does not ankylose except in a few cases such as Platanista. Even in some of the Pinnipedia there occurs a noticeable weakening of the jaw and looseness of the symphysis. However, in the walrus whose food consists chiefly of bivalve molluscs, the teeth are adapted to crushing the shells and the jaw is remarkably heavy and strong and in the adult the symphysis is thoroughly ankylosed. The crushing jaw of the Sirenia is also ankylosed. In general the pterygoid processes also tend to become reduced, and there is a tendency toward a looseness of articulation in all the bones of the head, particularly in the Cetacea.

The shifting of the external nares from a terminal into a more dorsal position is an adaptation to breathing at the surface of the water. This is accomplished by a shortening up of the nasal bones, which in the Cetacea become merely vestiges on the anterior surface of the frontals. In the Cetacea the opening is so shifted as to lie quite on top of the head, while in the Sirenia and Pinnipedia also the shifting is quite noticeable. It is a noteworthy fact that the true seals, Phocidæ, and the dugong, Halicore, which give other indications of a longer life in the water than the eared seals, Otariidae, and the manatee, Trichechus, respectively, have the external nares also more dorsal. The hippopotamus and the extinct rhinoceros, *Metamynodon planifrons*, also show a somewhat dorsal position of the nares. In many cases the external narial opening can be closed to exclude the water, as in Sirenia and Cetacea. In the Odontoceti the two external nares fuse into a single opening before reaching the surface, a condition paralleled by some of the crocodiles.

The internal nares are also shifted backward to bring the

opening more nearly over the epiglottis, and along with this in the Cetacea is found an intranarial epiglottis [1] formed by the prolongation upward of the epiglottis and the arytenoid cartilage into the nostril, forming an independent continuous passage from the exterior to the lungs. These are undoubtedly adaptations to the capture of food in connection with conditions of respiration at the surface of the water and permit of food being held in the mouth or even of being swallowed without interfering with respiration. In the Cetacea, naturally, the process is carried farthest, and here the extreme is found in such forms as Globiocephalus in which the postnarial opening is secondarily bridged over by the pterygoids and the palatines are entirely excluded from the anterior border. In Delphinapterus the palatines take part for a small space in the formation of the anterior border of the opening, and from this condition we find successive steps to that found in the less modified forms, as the Pinnipedia, where the whole border is formed by the palatines. The palatines are posteriorly elongated as the first step in the backward shifting of the internal nares, as shown by the Pinnipedia, Ornithorhynchus, etc. The reduction of the salivary glands is also to be noted. As the function of the saliva is chiefly a mechanical one connected with deglutition the reduction of the glands in forms taking their food in the water is easily explained.

The loss of the external ears is another noticeable result of aquatic life. In the Cetacea, Sirenia and Phocidæ the external ear is lost entirely, and among the eared seals, Otariidæ, it is found in various stages of reduction. The opening of the ear is often valvular so that it can be closed when in the water, and this condition occurs even among those forms which are only semi-aquatic, as in Crossopus and Neosorex. There is a tendency among certain forms, also, toward the arrangement of the ears, eyes and external nares in one plane near the top of the head so that all may come into use at once without exposing very much

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[1] Possibly this is to be looked upon as the persistence of a larval structure, as Howes has found an intranarial epiglottis in the young of a number of the more primitive mammals having a forced lactation by means of mammary muscles, and it is perhaps more than a mere coincidence that the whales have also a forced lactation.

of the head.   This is most marked in the hippopotamus but is seen also in the capybara and beaver and other forms.   In such forms the eye-sockets may be quite prominent.

The shortening of the neck is another manifestation of the tendency to take on a "fish-like" form, in connection with the question of locomotion.   In all truly aquatic forms this is noticeable. It is brought about by a great shortening up of the cervical vertebræ, and in extreme cases the loss of a vertebra (manatee) or the fusion of some or all of the cervical vertebræ may take place (most Cetacea).   The occipital condyles also tend to become flattened out and the odontoid process is reduced.   The final result of this process is an almost complete lack of motion between the head and trunk, a condition finding its parallel in the fishes, ichthyosaurs and other truly aquatic forms.   This loss of motion in the cervical region is more than compensated for, however, by the greatly increased power of motion attained by the more posterior portion of the body.   Here the intervertebral connections are simplified and the vertebral column rendered more mobile, since for the purpose of swimming, mobility of a certain sort in the posterior part of the body is most useful. The zygapophyses are progressively reduced and lost posteriorly in the Sirenia and Cetacea, and other processes such as anapophyses are entirely lost.   Also the pleurapophyses or ribs of the sacral region are lost as the pelvis loses its connection with the sacrum (Sirenia and Cetacea).   The spinous processes tend generally to reduction, as in the cervical and anterior dorsal region there is no need for the strong supporting muscles and ligaments of terrestrial forms, and connections for leaping muscles are lost posteriorly.   The spinous processes of the posterior body region and anterior caudal region seem to be secondarily elongated, probably in connection with the up and down motion of the tail in swimming, in many Cetacea, and the chevron bones of the anterior caudal region in some forms are also elongated.   The centra of the vertebræ become amphiplatyan in the Sirenia and Cetacea throughout most of the column, and the intervertebral cartilages become thicker especially posteriorly. The epiphyses, also, tend to unite at a very late period.

In all truly aquatic mammals the thorax takes on a character-

istic cylindrical form, there being little or none of the lateral compression such as is common among land forms, and this seems to be the first step in the enlargement of the chest capacity, as it is found in Pinnipedia as well as in the Sirenia and Cetacea. The ribs at first tend to become highly arched dorsally and then to move upward in their point of attachment from the centra to the transverse processes. The beginning of this process is found in the Pinnipedia and its culmination is seen in the whalebone whales, Balænoidea, where all the ribs are attached only to the transverse processes of the vertebræ. Possibly this is of service in equilibration as the lungs can take a more dorsal position. Accompanying these changes the diaphragm becomes much more oblique and much more strongly muscular, undoubtedly giving greater control over the chest capacity in the peculiar conditions of respiration necessarily accompanying aquatic life.

Perhaps the most striking external adaptation to aquatic life is the assumption of "fins" for use in swimming. Many of the Cetacea have developed a fleshy dorsal fin which undoubtedly serves the same purpose as the similar organ among the fishes and ichthyosaurs. The Sirenia and Cetacea have a large expanded caudal fin supported by a dense framework of connective tissue and used as a propeller in swimming. This organ differs from that of the fishes in being expanded laterally instead of vertically, and this arrangement of the fin permits the animal to rise to the surface more quickly for air and to dive again as readily, and it accounts for the peculiar undulatory motion so noticeable in these animals when they are swimming at the surface. The flukes of the tail are said to be capable of a somewhat rotary sweep like the blades of a screw propeller at each stroke of the tail. It is a noteworthy fact that nearly all aquatic mammals have this dorso-ventral flattening of the tail, the only exceptions being Potamogale, Myogale and the muskrats, Fiber and Neofiber which have the tail expanded vertically after the manner of a salamander. Potamogale is said to swim like a newt with the legs folded against the body, and to be an exceedingly rapid swimmer. The tail is so large and strong and functions so completely as a propeller that the limbs have not been modified even to the extent of webbed toes although the

animal is quite aquatic in its habits. In Chimarrogale, Necto-
gale and Crossopus there is a stiff fringe of hairs which may serve
the same purpose as the compression of the tail. The caudal
vertebræ are flattened laterally in Ornithorhynchus, Castor,
Halicore, and some Cetacea.

II. In the limbs, which at first play such a part in locomo-
tion in the water, we should expect to find marked adaptation.
Naturally those forms which move about occasionally upon the
land have the limbs less modified than those which have become
more completely aquatic, as progress upon the land calls for an
entirely different form of limb from that which is most useful in
the water. In some animals semi-aquatic habits have been
assumed while as yet no modification of the limb has taken
place. Thus in the water-vole, *Microtus amphibius,* there is no
trace of a web connecting the toes. Some other forms, as the
muskrats, have only rudiments of webs at the base of the toes,
while the minks have the toes partially webbed. The beavers
and the water-opossum, Chironectes, have the hind feet large
and fully webbed, while in the otters, the sea-otter and the duck-
bill, Ornithorhynchus, both feet are webbed to the claws. In
the more completely aquatic Pinnipedia the membranes, sup-
ported by connective tissues, reach beyond the digits, but the
claws are still present. In the Sirenia the whole forearm becomes
enclosed in the membrane and the last vestiges of the claws are
seen. The manatee retains slight vestiges of three nails,
(*T. inunguis* questionably), but the dugong and the extinct
Steller's sea-cow, *Rhytina stelleri,* lack the nails entirely. The
whales reach the climax of modification, as all of the limb out-
side of the body becomes enveloped, and the nails are entirely
lost (Leboucq has described the nails in the embryo). The
limb now becomes simply a balancing organ and the transition
from an ambulatory to a natatory limb is complete. Kükenthal
aptly says, " In exact ratio to the adaptation to aquatic life do
we find the membranes just indicated or uniting the digits or
enveloping them entirely." In lieu of webbing there is some-
times developed a stiff fringe of bristly hairs on the margins of
the feet as in Crossopus. This may be carried still farther by
the addition of a fringe of hairs on the sides of all the toes, as

in Chimarrogale, or in addition to the fringes the foot may be
widened by disc-like pads and at the same time be webbed as in
Nectogale and Myogale.

Another transformation due to life in the water is found in
the shortening of the arm and forearm and lengthening of
the digits. This begins in the Pinnipedia where the arm is con-
siderably reduced in length though it is still serviceable to some
extent in locomotion and in most cases capable of supporting
the weight of the body. In the Sirenia and Cetacea, where
progress upon the land has been entirely given up, the arm is
still more reduced and in the latter group may be entirely with-
drawn into the body wall, only the hand remaining outside to
form the fin. In both these groups, but in the latter especially,
the arm no longer functions as a propelling organ but serves, as
in most fishes, merely as a balancing organ, the greatly devel-
oped tail furnishing the motive power. The extreme of adapta-
tion in the hand is reached in the addition of extra phalanges in
the digits, hyperphalangy, and the addition of an extra digit,
hyperdactyly, thus increasing the extent of the hand. Hyper-
phalangy is common among the Cetacea, where as many as
twelve phalanges may occur in a single digit, and even a greater
number than this in one species, *Globiocephalus melas*. It
apparently does not occur in other aquatic mammals except
occasionally an extra phalanx may be found in Sirenia, but a
close parallelism is seen in the ichthyosaurs and plesiosaurs.
Kükenthal accounts for hyperphalangy as a result of retarded
ossification and the formation of double epiphyses. These
epiphyses tend to ossify at later and later periods and finally
to become entirely separate bones forming the extra phalanges.
As compared with other theories that have been advanced to
account for hyperphalangy, this theory of Kükenthal, strength-
ened by the array of facts which he brings to its support,
seems most reasonable and sufficient to account for the condi-
tions in the Mammalia at least. Hyperdactyly is not common
in the Mammalia but it is known to occur in some of the
Cetacea, *e. g. Delphinapterus leucas*, the white whale, by a
splitting of the fifth digit, as shown by Kükenthal and Leboucq.
In the ichthyosaurs the process went much farther, several sec-
ondary digits being formed.

Along with the change of function in the anterior limb occurs the absence of clavicles, the reduction of the sternum and the reduction and loss of articulation between the bones of the limb. The distal elements, carpals and phalanges, tend to become separated and imbedded in cartilage so that there is only a general flexibility of the hand, but the humerus, radius and ulna become exceedingly short and lose all motion upon each other so that there is not only no torsional motion of the radius and ulna but also no motion in the elbow joint. As a final expression of this the three bones often become ankylosed at the elbow in the Cetacea. There is also a noticeable flattening of the bones (the humerus is flattened distally only) and, connected with the change in function of the limb, there is a reduction of prominences for the attachment of certain muscles. Thus in the Sirenia and Cetacea the deltoid crest and the olecranon process become very much reduced. The entepicondylar foramen is also absent. The spreading out of the ulna and radius permits the intermedium to move up well between the distal ends of these bones in some of the Cetacea, a condition not found in any other group of mammals but paralleling the condition in Amphibia and many reptiles. The elongated sickle-shaped hand of Globiocephalus and some other cetaceans is paralleled by that of the Thalattosuchia and Ichthyosauria among the reptiles.

In the hind limb the story is somewhat different, according to whether or not the form in question possesses a tail fin. In the Sirenia and Cetacea which have this organ there is no function remaining for the hind limbs, as the balance can be preserved by the anterior limbs and the tail furnishes the motive power, and as a result the hind limbs are entirely lost, with the exception of the merest vestiges of the skeletal structures which have lost all connection with the vertebral column and are not at all visible externally. The reduction process in the pelvis begins even in the seals as the ilium never unites solidly with the sacrum as it does in land forms. In all the Pinnipedia, a tail fin not being present, the hinder limbs have gradually moved backward to assume the function of a propeller and a motion somewhat similar to the tail of the cetacean. In the Phocidæ, the true seals, this process has gone so far that the limbs have become quite bound

up with the tail and are entirely useless for locomotion on the
land.   It was this similarity in action and arrangement that led
Ryder in 1885 to derive the flukes of the tail in the Cetacea
and Sirenia from the hinder limbs, — a position no longer tenable,
as they are in no sense homologous.   In the hair seals, Otariidæ,
and walrus, Trichechidæ, the hinder limbs have not undergone
so much modification and are capable of being turned forward in
progression on the land, in which operation they are functional
to some extent.   With the change from the ambulatory to the
natatory limb there comes about necessarily a great change in
the musculature of the limb.

III.   The changes connected with the integument may be
noted as follows, — loss of hair, acquisition of blubber, loss of
the integumentary glands, smooth muscles and nerves of the
skin, and loss of dermal armature.   The loss of hair is usually
not marked in those forms which spend only a portion of the
time in the water, but in the more completely aquatic forms
there is almost an entire absence of it.   In the "hair seals,"
Otariidæ, which are the least aquatic of the group, there is a
fairly good coat of hair, and in the case of the fur-bearing species
this is intermingled with a dense coat of fine fur, but in the
walruses, Trichechidæ, and "true seals," Phocidæ, there remains
only short, appressed, coarse hair.   In the hippopotamus and
the Sirenia there remains but very little hair in the adult,
and again in the Cetacea we find remaining usually only the
merest vestiges and sometimes these occur only in the embryo.
Kükenthal has pointed out that all these forms are distinctly
more hairy in the embryo than in the adult (except in the case
of the white whale, Delphinapterus, and the narwhal, Monodon,
which have lost all traces of hair even in the embryo), thus
showing their origin from forms that were more hairy.   The
acquisition of blubber goes on *pari passu* with the loss of
hair, until in the Cetacea the blubber becomes extremely thick.
Kükenthal is responsible for the statement that in the seals
"hand and hand with the biological observation of the longer or
shorter time spent on land by the various species, we can deter-
mine the presence of a denser covering of hair or detect a
thinning of the coat, corresponding with the gradual increase of

the layer of blubber." The reason for this is to be found in the fact that hair is but a poor defense against the loss of heat when in the water, while the layer of oil constituting the blubber affords an excellent protection. Accompanying the loss of the hair we naturally find also a reduction in the sebaceous glands, smooth muscles and nerves of the skin. The sweat glands are also wanting in the Sirenia and Cetacea.

There are indications that the toothed whales, Odontoceti, have been derived from forms possessing a dermal armature. Kükenthal, to whom this observation is due has shown that in Neomeris there remains in the adult considerable vestiges of what must be looked upon as a dermal armor. This has been preserved usually only in those regions of the body where it may be useful as a protection, as on the anterior margin of the flippers, the anterior dorsal region and around the blow-hole, though traces may occur on other parts of the body. The study of the embryo shows that this is only a remnant of what was once a much more extensive dermal armor. In the porpoises is found the last appearance of this armor in the tubercles along the dorsal fin. Here also they are more abundant in the embryo. It is worthy of note in this connection that there have been found with the extinct zeuglodons certain ossicles which indicate a more extensive armor than is known to occur among recent whales. The loss of armor is paralleled a number of times in the marine reptiles. In the ichthyosaurs, the most aquatic reptiles known, Fraas has shown that the dermal armor was almost entirely lost, being retained only along the anterior border of the fore limb, — the same position in which it occurs in Neomeris.

Besides the adaptations already mentioned, it may be noted that the bones of the truly aquatic forms are light and spongy, particularly in the Cetacea, and in this group also the bones become impregnated with oil. In the Sirenia the bones are exceedingly dense and heavy, but in explanation of this it must be remembered that these forms are not pelagic but live along the shore in shallow water and find their food in the sea-weed growing upon the bottom. The very heavy skeleton seems to be an adaptation to bottom-feeding habits. In support of this

view it may be added that the walrus, which is a bottom-feeding form living chiefly upon bivalve molluscs, has the skeleton noticeably heavier than that of any other of the Pinnipedia which are generally piscivorous in habit.

The kidneys of most aquatic mammals are lobulated, Hippopotamus, Pinnipedia, Cetacea, but how this is to be explained by aquatic life is not clear.

The testes are retained within the abdomen in the Cetacea, Sirenia and the true seals, Phocidæ. In the less aquatic hair seals, Otariidæ, they are scrotal as in the majority of mammals.

Retia mirabilia, anastomoses of smaller arteries and veins, are abundantly developed in the Sirenia and Cetacea. These cause a slowing down of the blood stream and it has been suggested that this is connected with the oxidation of the blood in these forms that breathe infrequently.

In the foregoing enumeration of adaptations the writer has attempted to include only those that seem to be a result of aquatic life, but in certain instances these may be open to question. For example, Beddard has been inclined to question the loss of hair in the Cetacea and Sirenia as due to aquatic life, holding out the suggestion in the case of the whales that they have probably been derived from armored forms in which the hair was already lacking. That the Odontoceti have probably been derived in this way is true and it is also true that they have less hair than other marine forms, but it is equally true that hairs have been found, at least in the embryo, in all but a few species and in all cases these hairs are degenerate or vestigial in nature. The inference seems plain that the ancestors of these forms had these hairs better developed. As to the Mystacoceti and the Sirenia, which are almost equally devoid of hair, there is not the slightest evidence that they have been derived from armored forms. On the contrary it has been shown that in the embryo these forms are distinctly more hairy. This evidence taken in addition to the progressive degeneration of the coat observed in the Pinnipedia makes the reduction of the hair by aquatic life strongly probable.

In general it may be said for any character that when the same tendency is observed in two such widely separated groups

as the Sirenia and Cetacea (and the latter group is almost certainly diphyletic) it would seem difficult to explain on any other ground than similarity of environment. When a third group, as the Pinnipedia, shows the same tendency the matter becomes almost a certainty.

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AMITOSIS IN THE EGG FOLLICLE CELLS OF THE CRICKET.[1]

EDWIN G. CONKLIN.

THAT type of nuclear division known as amitosis or direct division which was once supposed to be universal is now known to occur so exceptionally that all teachers of cytology will welcome, I think, the announcement of its existence in great beauty and profusion in a common animal of wide distribution. It is this consideration which leads me to publish the observations here recorded which were first made more than six years ago.

It has been long known that one of the most favorable objects for the study of amitosis is to be found in the egg follicle cells of certain insects (*cf.* Carnoy '85, Korschelt '86, Preusse '95); in most if not all of these cases, however, it occurs only occasionally and must be searched for among many cells which do not show it. However in the case of the common crickets, *Gryllus pennsylvanicus, abbreviatus* and *domesticus*, every follicle cell in the enlarged portion of the ovarial tubes shows some stage or other in the process of direct nuclear division, and these cells are so easily prepared and they show every step of the division with such diagrammatic clearness that they cannot fail to become favorite objects for class demonstration.

A few words as to the structure of the ovarial tubes of the cricket and as to the best methods of preparing them for the demonstration of amitosis may not be out of place. If a mature female cricket, which can readily be distinguished from the male by the presence of the long median ovipositor, be torn in two it will be seen that a large part of the abdomen is occupied by the ovarial tubes which are arranged in two masses, one on either side of the body; these tubes are attached behind to the right and left oviducts and in front, by long slender filaments to

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the walls of the dorsal vessel. In fixing these masses of egg tubes it is advisable to tease them apart, otherwise the fixing fluids may not penetrate to the interior of the masses or the tubes may be difficult to isolate afterwards. Almost any modern fixing fluid will give good results, though I have had most success with picro-acetic (Boveri), picro-sulphuric (Kleinenberg) and Zenker's fluid. After hardening in alcohol the ovarial tubes may be stained from five to ten minutes in picro-hæmatoxylin [1] and then mounted entire; such tubes show beautifully not only the follicle cells in various stages of division but also the egg cells in different stages of growth. However, for the accurate study of the amitosis it is necessary to remove portions of the follicle by means of needles; this can readily be done after the tubes have been stained and dehydrated and while they are in the clearing fluid. These pieces of the follicle can then be mounted in balsam and, if desirable, can be studied under an immersion lens, though the nuclei are so large that all the details of the division can be made out with a magnification of from 125 to 300 diameters. It is advisable to double stain those tubes from which the epithelium is to be stripped, in picro-hæmatoxylin followed by a weak solution of eosin, or with acid fuchsin and methyl green (Auerbach's formula) in order to bring out the sharp contrast between the chromatin and the nucleoli.

Each ovarial tube of the cricket consists of a number of sections, all of which except the first contain ova in various stages of growth. These sections are, Fig. 1, (*1*) the terminal filament, a thread of considerable length but of small diameter which serves to attach the tube to the walls of the dorsal vessel; (*2*) an enlarged section, the terminal chamber, which contains ovogonia and young ovocytes which are not arranged in a linear series; (*3*) a varying number of small ovocytes or eggs which are arranged in linear series but are not completely separated from one another by constrictions of the tube; (*4*) a section in which the egg cells are separated by deep constrictions, the epithelial cells growing all the way through the tube and thus form-

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[1] Delafield's hæmatoxylin . . . . . 10 cc.
Distilled water . . . . 40 cc.
Kleinenberg's picro-sulphuric (stronger) . . 10 drops.

ing partitions between the eggs; in this
section all the eggs are of approximately
the same diameter, but the lower ones
are much longer than the upper ones;
(5) a section consisting of two or three
eggs, each succeeding one being about
four times the volume of the preceding
and all being enormously larger than
any of the ova in the other sections of
the tube.   Finally each of these tubes
is attached to one of the two oviducts,
through which the ripe ova escape.

In all sections of the tube the egg
cells are covered by epithelial cells; in
the second and third sections these cells
are relatively large and their nuclei are
far apart; in the fourth section they are
small and the nuclei are closely crowded
together, at the same time many of the
nuclei come to lie beneath the surface
layer and some of them seem to be
completely isolated in the yolk, to the
formation of which they probably con-
tribute.   In the second, third and fourth
sections of the tube the cells increase
rapidly by division, the nuclei always
dividing by mitosis; in these sections I
have never seen a case of amitosis.   The
ovarial tube is not as the name might
lead one to believe a tube composed of
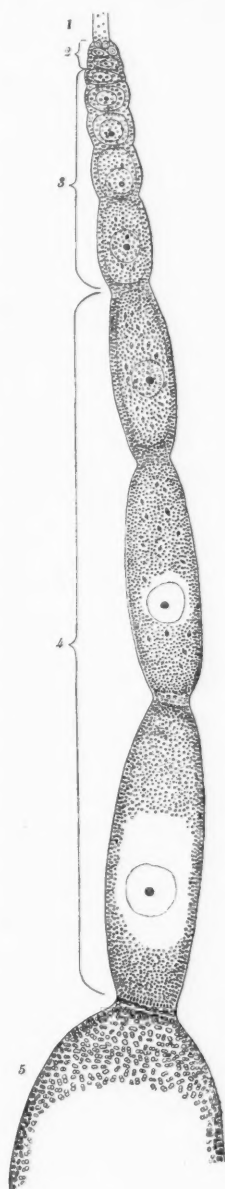follicle cells through which the ova

Fig. 1.—Ovarial tube of cricket; *1*, terminal filament;
2, ovarial chamber; *3*, section in which individual eggs
are not separated by follicle cells; *4*, section in which
eggs are completely separated by the ingrowth of
follicle cells; *5*, last section of tube containing two or
three large ova; in this section all nuclei of follicle
cells are in process of amitotic division.   × 62.

descend from one section to another ; on the other hand in all
the sections below the ovarial chamber each ovum is perma-
nently surrounded by its own follicle cells which descend with
the ovum and increase in number with its growth in size.   The
extent to which these follicle cells multiply can be estimated by
comparing their number in the fourth section with that in the
second, which would indicate that the increase cannot be less
than a hundred fold.   In the fifth section mitosis rarely if ever
occurs, but here all the nuclei are found to be in some stage
of amitosis.   In spite of the fact that all of the follicle cells of
this section are found in process of division the increase in the
number of the cells and nuclei in the successive segments of
this section is not great, not nearly as great as in the preceding
sections.   Coincidently with the great growth of the egg cells
in this section the follicle cells and their nuclei grow rapidly in
size though they do not increase rapidly in number ; this would
indicate that the process of amitosis is here a very slow one,
which may, perhaps, account for the fact that it is to be seen in
all the nuclei.

Figures 2 and 3 represent portions of the follicle from the
region of the ovarial chamber and just below it ; both show char-
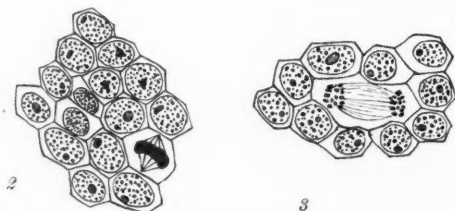acteristic mitoses but no evidence of amitosis in any of the cells.

FIG. 2.—Fragment of epithelium from the ovarial chamber (section 2) showing mitosis.
     × 900.
FIG. 3.—Fragment of epithelium from section 3 of the egg tube, showing mitosis.   × 900.

Figures 4–8 however taken from the greatly enlarged portion
(fifth section) of the tube show every nucleus in process of amito-
tic division.   In this division, as is shown in all the figures named
but particularly well in Fig. 5, the nucleolus first elongates and

then becomes constricted in the middle.   The elongation and
constriction of the entire nu-
cleus follows after that of the
nucleolus.   After the nucleolus
has completely divided into two
the nucleus also divides, but
although two separate daughter
nuclei are frequently found in
these follicle cells I have never
seen any indication of a division
of the cell body.   After the
first amitotic division of the
nucleus the nucleolus in many
cases elongates again and divides
in an axis at right angles to that
of its preceding division so that

FIG. 4.—Fragment of follicular epithelium
from the first egg in the fifth section of
the egg tube.   × 333.

two nucleoli are present in each of the daughter nuclei, Fig.
5.   The daughter nuclei may also become elongated and even
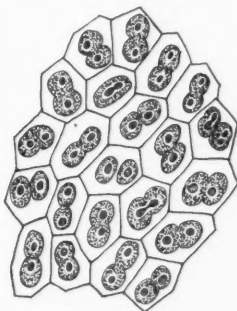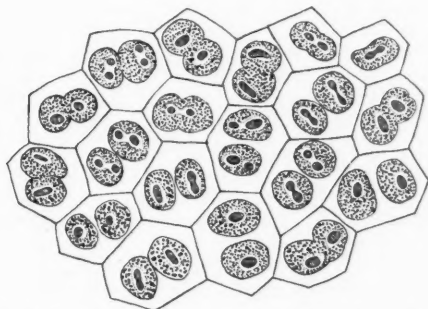constricted in the middle, but I have never seen them com-

FIG. 5.—Follicular epithelium from the second egg in the fifth section of the egg tube.
× 333.

pletely divided into four nuclei within the single cell.   This
division of the nucleolus and nucleus is almost always an equal
one and it usually occurs in a plane parallel with the surface
of the epithelium.

It is interesting to note that this case of amitosis almost

exactly corresponds to the type described by Remak in '55. He maintained that "cell division proceeds from the centre toward the periphery. It begins with the division of the nucleolus, is continued by simple constriction and division of the nucleus and is completed by division of the cell body and membrane" (Wilson, : 00, p. 63). For a score of years after Remak's work this was supposed to be the prevalent if not universal type of cell division. Then it gradually came to be recognized that karyokinesis or mitosis was the usual form of nuclear division and that amitosis was comparatively rare, in fact its very existence was
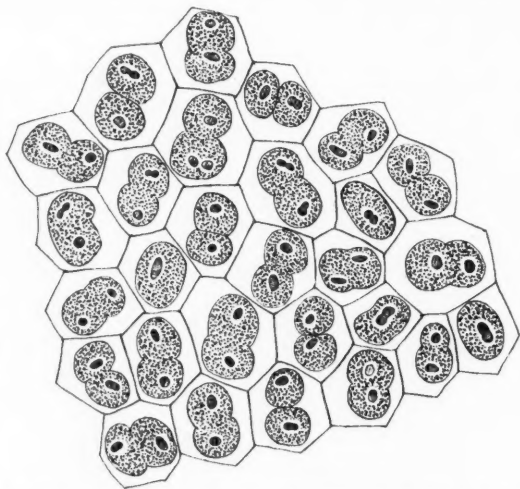
FIG. 6.—Follicular epithelium from the third and largest egg in the fifth section of the egg tube. × 333.

called in question. In particular the type of Remak which begins with the division of the nucleolus was found to be most unusual, being as Wilson says (: 00, p. 115) "one of the rarest forms of cell division (!)." Such preliminary divisions of the nucleolus have been described by Carnoy ('85) in the egg follicle cells of the mole-cricket, Gryllotalpa, and also in Lithobius and in Geotrupes, by Wheeler ('89) in the follicle cells of Blatta, by Hoyer ('90) in the intestinal cells of the nematode, Rhabdonema, by Korschelt ('95) in the intestine of the annelid,

Orphryotrocha, by de Bruyne ('97) in the follicle cells of several
insects and by Montgomery ('98) in the peritoneal cells of
Polydora.   In none of these cases however is it found so
abundantly and so plainly as in the follicle cells of the cricket.
I have examined the follicle cells of a number of insects and am
surprised to find how infrequent amitosis is in most of them.
In the mole cricket, as in all the species of true crickets which I
have examined it occurs in great profusion, but in the case of
the former the division of the nucleus is brought about by a deep
constriction on one side only of the nucleus.   In the grasshopper
the nuclei are spherical and not bilobed and rarely show any indi-
cation of amitosis and the same is true of several other insects
which I have examined.

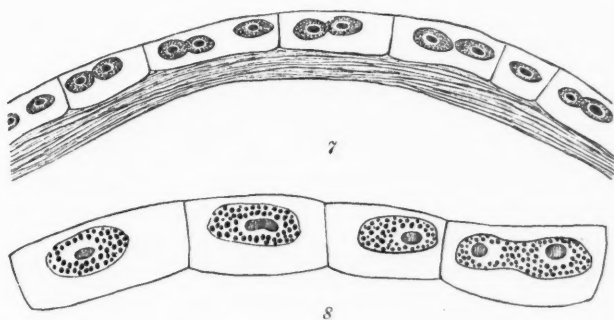In most cases of amitosis the nucleolus does not divide and a

FIG. 7.—Section through the follicular epithelium and underlying chorion of the smallest egg
in the fifth section of the egg tube.   × 333.

FIG. 8.— Section through the follicular epithelium of the largest egg in the ovarium tube.
× 333.

regular division of the nucleolus into two equal parts, preceding
an equal division of the nucleus such as is found in the cricket
is an occurrence of such rarity as to render it unusually interest-
ing.   Another peculiar feature of these divisions is that the
nucleolus is always surrounded by a clear faintly-staining area
free from chromatin.   This area is probably not the result of
shrinkage since it is found after all of the best methods of fixa-
tion which show no traces of shrinkage in other parts.   This
clear zone around the nucleolus elongates with the elongation

of the nucleolus and after the division of the latter it also divides (Fig. 5). In the elongation, constriction and division of the nucleolus into equal parts and in the presence of this clear peripheral layer which also elongates and divides, the nucleolus in the follicle cells of the cricket is very unlike ordinary nucleoli, while in both of these respects it resembles an intranuclear centrosome or "centro-nucleolus." Whether this resemblance is merely a superficial one without significance (analogy) or a fundamental likeness (homology) cannot be affirmed without a more extensive study of the structures in question, particularly of the fate of the centrosomes which are found in the mitotic divisions in the upper portions of the tube. If it should turn out that these nucleoli are really comparable to centrosomes their peculiar structure and form of division would find a ready explanation.

The biological significance of amitosis in this case cannot be a matter of much doubt. These amitotic divisions are found only in the terminal segments of the ovarial tubes at which time the follicle cells are actively secreting the chorion (Fig. 7). After the formation of the chorion and before the egg is laid these cells completely degenerate and disappear. A follicle cell which has once divided by amitosis never again divides mitotically ; in fact no mitoses are ever found in this terminal section of the tube. These facts all indicate that the amitotic division is, in this case, one of the last functions of these cells and that it is therefore an accompaniment of cellular senescence and decay.

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# NEW SPECIES OF PLANTS FROM THE MATAWAN FORMATION.

EDWARD W. BERRY.

In a recent Bulletin of the New York Botanical Garden [1] I have enumerated sixty-seven species of plants from the Matawan formation (Mid-Cretaceous) describing fourteen species as new to science. Additional collections from near Cliffwood, New Jersey, the only locality within the formation where recognizable plant remains have been found, disclose numerous additions to this Flora, among which the following species have been singled out as new ; and it has seemed best to publish them in advance of more extended treatment which might be long delayed. The remains are all from the lower portion of the Matawan formation known as the Crosswicks Clays. The types will be deposited in the paleobotanical collection of the New York Botanical Garden.

Confervites dubius sp. nov. Fig. 9.

Remains referable to this genus have not heretofore been recorded in this country, and as their microscopical characters are obliterated, it cannot be certain that they are algal in nature and not the macerated fibres of some higher plant. The disposition of the remains which are flexuous and interlaced would indicate the former view, and as a well marked type of vegetable remains they deserve a place in the flora of the Matawan formation. A number of foreign species have been referred to this genus,[2] comparisons with which would be useless in view of the unsatisfactory nature of the remains. Judging from the figured

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[1] Vol. 3. No. 9. Sept., 1903.

[2] Schimper, *Pal. Végét.* 1869, Tom 1, p. 154, lists eleven, mostly Tertiary species, all from European localities.
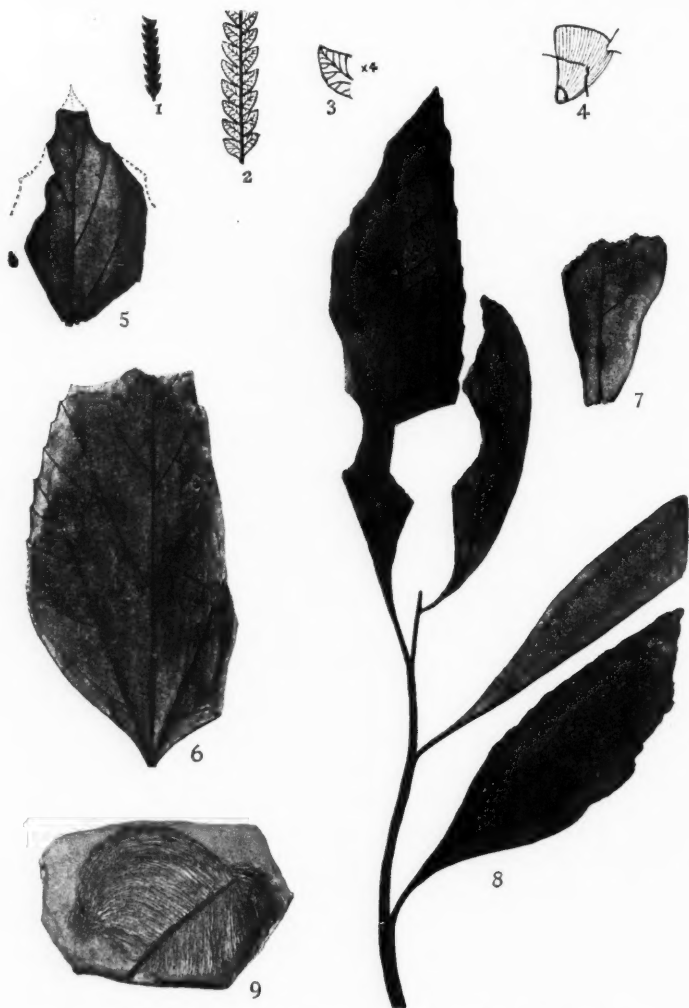
FIGS. 1-3, *Gleichenia saundersii*; 4, *Pinus mattewanensis*; 5 and 6, *Viburnum hollickii*; 7 and 8, *Myrica heerii*; 9, *Confervites dubius*. Fig. 3 enlarged, all others four-fifths natural size.

specimen[1] our form is practically identical with that of *Confervites aquensis* Deb. & Ett., from the lower Senonian of Westphalia.

Gleichenia saundersii sp. nov. Fig. 1–3.

In the flora of the Matawan formation I called especial attention to the total absence of ferns in that formation. Recent collections contain three characteristic fragments of what I regard as a new species of Gleichenia, adding another to the considerable list of types common to the floras of the mid-cretaceous Atlantic coastal plain and that of Greenland. The larger fragments are each about 3 cm. long and 7 mm. wide and the smaller is 16 mm. long and 3 mm. wide. Pinnules broadly falcate-ovate, entire, bluntly pointed ; attached by a wide base, about as wide as the pinnule is long ; length 4.5 mm. ultimately becoming much smaller, each with a stout mid vein which sends off alternately on each side rather thick veins to the margin, those running distad are all simple except the basal one which is sometimes forked, those running proximad are usually once forked ; texture thick and coriaceous.

Three species are found in the underlying Raritan formation, *Gleichenia giesekiana* Heer is larger with longer narrower pinnules, *Gleichenia micromera* Heer is much smaller with narrow linear right-angled pinnules, and the widespread *Gleichenia zippei* Heer has narrower pinnules with more rounded apices.[2] The only other coastal plain species is the fragment which Hollick[3] refers to *Gleichenia gracilis* Heer, which is about the same size as the Cliffwood fern but has the pinnules more acute and runcinate. This reference of Hollick's was only provisional as he did not wish to found a species on so small a fragment. His specimen is quite distinct from the Matawan form and also seems to be distinct from Heer's type ; unfortunately the venation cannot be made out. The numerous Greenland species

[1] Hos. & v. d. Marck, *Palaeont.* 26: 177. pl. 36, f 135. 1880.

[2] Since the above was written small, poorly preserved fragments of the latter species have been detected in the Matawan formation by the writer.

[3] *Ann. N. Y. Acad. Sci.* Vol. 11, 1898, p. 57, pl. 3, f. 3.

have usually smaller pinnules; there is some similarity with *Gleichenia acutiloba* Heer, the venation being much the same, but the pinnules are smaller and more acute. The species is named for its discoverer Mr. B. H. Saunders of Clifton, N. J., who has collected a number of valuable specimens in the Clay-Marls.

The genus Gleichenia is a most interesting one. In the living flora it has about twenty-five species, widely distributed throughout the tropics of both hemispheres, subtropical eastern Asia, and the humid regions of the southern zone. The fossil species are equally numerous and widespread. Aside from those forms from the Paleozoic and older Mesozoic which have been referred to the Gleicheniaceæ, which reference is not altogether conclusive, as they probably represent synthetic forms from which the later species may have been derived, the genus enjoyed a wide adaptive radiation during the lower and middle Cretaceous. In the lower Cretaceous (Kome) of Greenland Heer has described fifteen species of Gleichenia, only one of which ranges as far south as the Potomac formation; one other occurs in the lower Cretaceous of the continental interior. By the mid-cretaceous several of these Greenland species had become wide-spread, identical species occurring in such widely separated localities as Europe and Kansas, or Europe, Greenland and New Jersey; four of the Greenland species find their way south along the Atlantic coastal plain and three reach Europe. Two species occur in the Laramie after which the species disappear. With the gradual refrigeration of Tertiary climates the Gleicheniaceæ moved southward, the only American fossil species of that age being the doubtful *Gleichenia obscura* Kn. from the late Tertiary (Esmeralda formation) of Nevada. This southern movement probably continued until Glacial times sending the Gleicheniaceæ into the West Indies, along the Andes into South America, along the eastern Asiatic coast, and across southern Europe into Africa.

Pinus mattewanensis sp. nov. Fig. 4.

The well characterized impression of a single winged seed is among the material from Cliffwood, N. J. Length 13.25 mm.;

greatest width 10.5 mm.; veins .75 mm. apart; proximal margin nearly straight; apex broadly truncate. Newberry [1] figures fragmentary winged seeds together with leaves from the underlying Raritan clays at South Amboy, N. J., and Hollick [2] figures leaf fragments and a single seed (Fig. 19) from Tóttenville, Staten Island, in approximately synchronous strata, but no remains referable to this genus have hitherto been found in the Matawan formation. The specimen is unaccompanied by leaves although poorly characterized remains of the latter are found in the same formation. I have been unable to refer the seed to any described species, none of which are nearly so wide, and the same may be said of the existing species with which it has been compared. In outline it is approached by the seeds of some of our western species of Picea and it is also very similar to the seeds of *Cedrus deodara* Loud.

In the living gymnospermous Flora Pinus is a dominant genus with about seventy species widely distributed throughout the northern hemisphere, thirty-nine of these occurring within the limits of the United States. The fossil species are likewise numerous (though many are of uncertain value) ranging from the older Mesozoic upward. The genus becomes greatly developed in the later Cretaceous and early Tertiary of the Arctic regions, Greenland furnishing nine Cretaceous and six Eocene (?) species and Spitzbergen four Cretaceous and twelve Eocene (?) species, some of them widespread; thus *Pinus palæostrobus* (Ett.) Heer ranges from Switzerland and Tyrol to Florissant, Colorado, occurring in the Baltic Tertiary, in Greenland, Grinnell Land and Spitzbergen. *Pinus quenstedti* Heer is likewise cosmopolitan, occurring in the Cenomanian of Moravia, Silesia, and Bohemia, in Spitzbergen, in the Dakota group of Kansas, and in the Montana formation of Wyoming. *Pinus* (*Cyclopitus*) *nordenskioldi* Heer ranges from the Rhetic beds of Norway and Spitzbergen to the Kootanie of British Columbia.

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[1] *U. S. Geol. Survey*, Monograph 26, 1896, p. 48, pl. 9, figs. 17, 18.
[2] *Trans. N. Y. Acad. Sci.* Vol. 12, 1892, p. 4, pl. 1, figs. 13, 19, 20, 22.

Myrica heerii sp. nov.   Figs. 7, 8.

This is one of the finest specimens that I have found in the
Matawan formation, consisting of a twig and four attached
leaves which are complete except for their apical portions ; the
block of clay in which they were found contains several more of
these leaves which cannot be uncovered without destroying the
specimen figured.   The remains indicate a lanceolate leaf 13–14
cm. long by 2.7 cm. in greatest breadth ; base tapering, narrow,
gently incurved ; the larger leaves have wide and regular,
strongly undulate, almost toothed margins ; two of the leaves
are only slightly over one third the size of the larger and have
entire margins ; petioles comparatively long and moderately
stout ; leaf substance thick, with apparently immersed venation,
as only a few secondaries can be made out on the impression of
the under side of the largest leaf ; they leave the midrib at a
wide angle and are nearly straight almost to the margin where
they fork at a wide angle ; their ultimate disposition cannot be
made out.   The general similarity of size, shape and margin ally
these leaves to Myrica.   Seven species occur in the underlying
Raritan clays, all of which are much smaller except *Myrica emar-
ginata* Heer which approaches our smaller leaves in size ; it is
emarginate however and has entire margins and more ascending
secondaries.   Three species have been found in the Staten
Island Cretaceous, one of which *Myrica hollicki* Ward is even
larger than our leaf, which it resembles greatly except that the
margin is more dentate.   This species (*hollicki*) might be con-
sidered ancestral to the widespread Tertiary *Myrica banksiæfolia*
Unger which in turn was considered by Lesquereux as the
possible ancestor of the living *Myrica californica* Cham. of the
Western United States.   The latter might easily be the descend-
ant of our Matawan leaf, some specimens seen by me are iden-
tical except for their slightly smaller size ; other specimens are
more dentate ; no other living species that I have seen so
nearly approaches the Matawan species in the character of the
undulations of the margin, although nearly all of the Myricaceæ
are very variable in this respect, the same species often having
entire, or undulate, or dentate leaves on the same twig ; this is

particularly so in our common *Myrica cerifera* Linn. which might also be derived from the Matawan species. It is at least related and except for its somewhat smaller size and the irregular nature of the marginal characters it is strictly comparable.

The Cliffwood leaf is also very similar to *Myrica* (?) *trifoliata* Newb.[1] in size, shape and margin, but is longer petioled and not trifoliate. Among the ten species found in the Dakota group are several approaching ours in size, the one most similar, *Myrica aspera* Lesq.[2] has the same texture, size and margin ; the base of the former is however narrower, the venation more obsolete, the midrib more slender, and the petiole considerably longer if we may judge from Lesquereux's figure which appears to be that of a sessile leaf. This species has also been mentioned as the possible ancestor of the living *Myrica cerifera* Linn.

Myrica torreyi Lesq. is the possible descendant of *Myrica heerii* in the Montana and Laramie formations, with more pronounced marginal teeth. A number of unrelated Cretaceous leaves are somewhat similar in form and margin, as for instance *Ilex borealis* Heer, *Elæodendron speciosum* Lesq., and *Rhus powelliana* Lesq., but all differ in other particulars. Another species from the Dakota group which resembles our leaf is referred by Lesquereux to the somewhat smaller leaved species *Proteoides acuta* Heer. Like the Matawan leaf this also contains smaller entire margined leaves, but the tip is more extended, the undulations of the margin are wider, and the base indicates that the leaves were sessile.

Viburnum hollickii sp. nov. Figs. 5, 6.

Viburnum whymperi Heer, Knowlton, *Bull. U. S. Geol. Surv.* 163. pl. 19, f. 3. 1900 (*non* pl. 17 f. 1, and pl. 18 f. 1).

The remains consist of the major portions of several leaves indicating an ovate leaf between nine and ten centimeters in length by 5 cm. in greatest breadth ; apex and base acute ; basal secondaries opposite, long, ascending in a nearly straight line from the decurrent base, giving off three or four tertiaries on

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[1] Undistributed plates, *XIV.* f. 2. from Dakota group of New Mexico.
[2] *U. S. Geol. Survey*, Monograph 17, 1892, pl. 2, f. 2.

the outside which run to the teeth of the margin ; angle of divergence acute, about 30° ; a considerable interval to the next pair of secondaries which leave the midrib at an angle of about 40° and ascend in a slight curve to the margin ; the three or four succeeding secondaries on each side become more and more ascending and are unbranched ; margin for the basal third entire, upper two-thirds shallow-toothed ; nervilles per-current at right angles to the secondaries ; midrib thin and straight.   I have tentatively included under this species a leaf from the Montana formation which Knowlton (*loc. cit.*) doubt-fully refers to *Viburnum whymperi* Heer, a Tertiary species from which it manifestly differs.   It differs from our type in the lower secondaries being sub-opposite and supra-basilar, otherwise it is markedly similar.   The genus Viburnum has been heretofore unrepresented in the flora of the ancient Atlan-tic coastal plain, the species *Viburnum integrifolia* referred by Newberry to this genus being an entirely different leaf.   Three species occur in the Patoot beds of Greenland and abundant remains are found in the western interior from the Dakota group upward.   Among the twelve species and varieties from the Dakota group only one, *Viburnum sphenophyllum* Kn. resembles the Matawan leaf.   From this species ours differs in its larger size, more ovate outline, lesser number of secondaries, which are also more ascending and slightly more curved ; the margin is less prominently dentate and the basal third is entire ; a pair of secondaries leaves the base at an acute angle ; these are wanting in *sphenophyllum* where all the secondaries are parallel, the first pair leaving the midrib 3 mm. above its base at an angle just twice as wide as in our type.   In the existing flora the nearest analogues of *Viburnum hollickii* are to be found among the occasional simple leaves of the normally lobed species such as *Viburnum acerifolium* Linn. and *Viburnum opu-lus* Linn.   The normally simple leaved forms have numerous parallel secondaries and more toothed margins although the outline is quite similar in *Viburnum cassinoides* Linn., *Vibur-num lentago* Linn., and *Viburnum nudum* Linn.

PASSAIC, N. J., July 12, 1903.

SOME REMARKS ON THE FOSSIL FISHES OF MOUNT LEBANON, SYRIA.

O. P. HAY.

IT IS sometimes the good fortune of the archæologist to carry his excavations into the site of some long ago forgotten village or city, and there to unearth the relics of its former inhabitants. From these remains, perhaps scanty and broken, he essays to determine the manners and customs of the people, their religion, the grade of their civilization, the nature of their intercourse with the neighboring tribes, and perhaps to learn what ancient practices yet persisted and what new ones were coming into vogue.

To the palæontologist the earth's crust, in its breadth and thickness, is a burial ground from which he may exhume the remains of the animals and plants that once lived on its surface or in its waters. The words of Bryant, spoken of the races of men, may truthfully be applied to other living things,

> "All that tread
> The globe are but a handful to the tribes
> That slumber in its bosom."

But there are spots where the carcasses are sown thicker and have been better preserved than elsewhere ; and to such places the scientific birds of prey, who seek for, and must usually be satisfied with, fragmentary bones, and imprints of skeletons, and scattered scales and teeth, are gathered together ; and, fed on such booty, they have visions of the swarms of animals, fat, sapid, and comely, that once populated the earth.

The Cretaceous period is one of great interest to the palæontologist. It was a part of that long period which has been well called the Mesozoic ; it was the closing third of the medieval age of the world's history. During the Cretaceous, vast advances were made in the extinction of ancient forms of life and in the

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introduction of the present order of things ; so that, with the ushering in of the Tertiary, the world had become utterly transformed from the condition it had at the beginning of the Cretaceous.

In the present paper we are to consider the fishes of the upper Cretaceous period, especially those found in Mount Lebanon, Syria.

The fishes of the Upper Cretaceous come to us principally from four regions far removed from one another. One of these is in western Kansas, another in the south of England, a third in Westphalia, and the fourth in Syria. Our knowledge of the fish-bearing strata of Kansas is of comparatively recent date ; the other beds have long been known. Davis, who has written an important paper on the fossil fishes of Mount Lebanon, tells us that they were known to Herodotus, 450 years B. C. Travellers within the six hundred years preceding the nineteenth century often expressed their astonishment at finding such perfect resemblances of fishes when the fissile rocks of that region were split open. Accurate and scientific descriptions of these remains have been presented only since the beginning of the nineteenth century. Blainville, Agassiz, Pictet, Humbert, Heckel, Davis, and A. S. Woodward have been the principal writers on the subject.

While fossil fishes seem to have been found in several localities in Syria, two have become especially famous, Sahel Alma and Hakel. The former is a village about eleven miles northeast of Beirut ; Hakel is situated about twenty-three miles somewhat northeast of Beirut, and six miles from Jebeil, the ancient Byblus.

Recently a third locality has been explored. This is near a village called Hajula, situated about six miles south of Hakel. About two years ago, at the instance of Rev. D. Stuart Dodge, of New York City, this locality was visited by Alfred Ely Day, professor of geology in the Protestant Syrian College at Beirut ; and this gentleman succeeded in making a large collection of fossils, especially of fishes. He collected many fishes at Hakel also ; but he was not permitted to work at the classical locality, Sahel Alma. A large part of Professor Day's collection was

presented by Rev. D. Stuart Dodge, in behalf of the Protestant
Syrian College, to the American Museum of Natural History,
in New York, and the present writer has had the opportunity
of studying and describing them.   An account of the interesting
things in this collection, illustrated by fourteen plates, has
recently been issued by the Museum (*Bull. Amer. Mus. Nat.
Hist.*, Vol. 19, pp. 395–452, pls. 24–37).

From the fish-beds at Sahel Alma there have been described
about sixty species of fishes; from Hakel, fifty species; and
now there come from Hajula thirty-four species.   Doubtless
further collecting at Hajula will much increase its number.
The fishes found at Sahel Alma belong, in general, to the
same genera as those at Hakel and Hajula; but, of its sixty odd
species, probably not one is found at the other localities.   On
the other hand, twenty-one species that have been secured at
Hajula occur also at Hakel.   These data make it quite certain
that the beds at Sahel Alma are on a different level from those
at Hakel and Hajula; while those at the latter places are on the
same, or nearly the same, horizon.   Opinions have differed as
to which are older, the fish-beds at Sahel Alma or those at
Hakel; but it is apparently the view of the best modern author-
ities that those at Hakel are more ancient.   This opinion
appears to be supported by the character of the fishes in each.
From a study of the fishes taken at Hajula the writer has con-
cluded that the beds containing them belong to a slightly more
recent time than that of the beds at Hakel.

As to the position of the fish-bearing strata of Mount Lebanon
in the geological scale, all authors now agree that they belong
to the Upper Cretaceous.   The epochs of this division, as rec-
ognized in Europe, are, beginning with the lowest beds, the
Cenomanian, the Turonian, the Senonian, and the Danian.
Some authorities have assigned the fishbeds of Mount Lebanon
to the Turonian, others to the Senonian.   A. S. Woodward,
in the earlier pages of the first volume of his splendid work,
Catalogue of Fossil Fishes, credits the Mount Lebanon fishes to
the Turonian, but in the later pages they are said to belong to
the Senonian.   In the third volume they are more definitely
referred to the Upper Senonian; but in the fourth volume they

are cited simply as coming from the Upper Cretaceous. The deposits from which the fossil fishes of Westphalia are exhumed are regarded as Senonian. Rœmer (*Zeitschr. deutsch. geol. Gesell.* vol. 6, 1854, p. 201) assigns these beds to the older Senonian. Lepsius (*Geol. Deutschlands*, vol. 1, p. 177) and Credner (*Elem. Geol.*, p. 637) regard them as belonging to the Upper Senonian. A comparison of the genera and species of fishes from Mount Lebanon with those from Westphalia has convinced the present writer that the horizons of the two groups of beds are practically the same, and that the Mount Lebanon fishes, therefore, belong to the Upper Senonian. Hence these fishes lived near the close of Cretaceous times ; and we are enabled to observe the advances which this group of animals had made during this long age.

At the beginning of the Cretaceous the shark-like animals were few, so far as the record shows, and these mostly of now extinct genera. There were doubtless species of Hexanchus (Notidanus), a decadent genus represented now by the cow sharks ; for we know that species lived during the Jurassic. There was a member or two of the Heterodontidæ (Cestra-ciontidæ), and possibly the Lamnidæ were represented. No rays or sawfishes are known from the Lower Cretaceous, but there must have been species of Rhinobatus, since they had previously existed and the genus is yet on the earth. But with the open-ing of the Upper Cretaceous, in the Cenomanian, the Lamnidæ and the Scylliidæ were well established ; while in the Senonian beds at Sahel Alma there were three or four species of each family. At Hakel only a single species of shark, *Otodus sulca-tus*, has been found ; at Hajula, no shark.

Of the rays there are interesting forms at all three of the Mount Lebanon localities. A. S. Woodward has described from Sahel Alma the rostrum of a primitive sawfish, *Scleror-hynchus atavus*, the rostral teeth of which are not in sockets and which, as they are followed backward, graduate into the shagreen scales of the side of the head. In the collection from Hajula the writer has found three new species, one represented by a considerable portion of a rostrum ; another, by a complete rostrum and a considerable part of the head ; and a third, by

much of the rostrum, the head and most of the pectoral fins. There is likewise the trunk of a species of the genus present. These specimens show that Sclerorhynchus belongs to the Pristidæ, and further, that at that far away day the sawfishes resembled closely those of our time, except in the mode of attachment of their rostral teeth.   Between that time and the Eocene, these modified shagreen scales found deeper and deeper lodgement in the cartilages of the rostrum, attained greater size, and became the efficient weapons that we find them to-day.

The new Sclerorhynchus which is represented by the rostrum alone has been called *S. sentus*, because on one flat side of the rostrum there are two rows of short spines.   The species represented by the complete rostrum has been named *S. solomonis*, in recognition of the interest of the great Israelitish king in natural history (i Kings, iv, 33).   The third species is to be known as *S. hiram*, in honor of the friend and ally of Solomon.

Of the genus Rhinobatus three species have already been described from Sahel Alma and one from Hakel.   A new one, *R. eretes*, is found in the collection from Hajula.   Likewise a new ray comes form Hajula, and this has been named *Raja whitfieldi*, in honor of Prof. R. P. Whitfield, of the American Museum.   It is surprising to observe how little these rays have changed since those Senonian times.

Of the true fishes, Pisces, we find in the Mount Lebanon fish beds but few representatives of the old families of the Jurassic. None has been obtained at Sahel Alma, and this speaks for the later time of these beds.   From Hakel there have been known four species of pycnodonts; and now from Hajula there is secured a new one, *Coccodus insignis*.   It is represented by many specimens, some of them quite perfect; and is characterized by having a short and compressed occipital spine.   It likewise presents clear evidences of pectoral and ventral fins.   Hakel furnishes a new and strange fish which possibly belongs to the Belonorhynchidæ, and which has been named *Stenoprotome hamata*.   The head, as it is shown on the matrix, resembles in miniature that of the African antelope, Bubalis, even to the horns. The horns, or spines, are probably connected with the operculum. The tip of each is very sharp, and just below this there is a

barb, like that of a fishhook.   There seem to have been no
vertebræ, and the body has been covered with bony plates.

The Macrosemiidæ and Oligopleuridæ, scantily represented at
Hakel, have not yet been found at either Sahel Alma or Hajula.
Some of the fishes of the Upper Cretaceous had already acquired
many of the characters which are found in our modern forms.
In the majority of them the skeleton was extensively ossified,
the vertebræ were as we find them to-day, the fins had lost their
fulcra, and in many cases the rays had become spinous.   A
number of the families that still persist had already come into
existence, and this is true of a few genera.   The Elopidæ, best
known by the tarpon of our southern waters, are recognized in
eight species at Sahel Alma, three at Hakel, and one at Hajula.
None of the species begins to attain the size of the tarpon.
The Ichthyodectidæ, a family close to the Chirocentridæ, is
thought to be represented at Hakel and Hajula by a species
which Woodward calls *Ichthyodectes libanicus,* but which the
present writer refers to a new genus, Eubiodectes, that is,
a biter that gets a good living.   It grew to a size somewhat
greater than that of the shad.

Ctenothrissa is a genus which stands as the type of the
Ctenothrissidæ.   It possessed many of the structures that are
greatly in vogue in our own day among the denizens of the deep.
It had serrated scales, and the ventral fins had been moved for-
ward to a position just below the pectorals.   The writer has
described a new and beautiful species, *Ctenothrissa signifer,*
from Hajula.   It is characterized by the possession of very high
dorsal and anal fins ; and the ventral rays likewise were greatly
elongated.

The Clupeidæ, so abounding in genera and species in the salt
and fresh waters of our time, were present in force during the
Senonian ; but only one of the genera of that time has survived.
Two species of Scombroclupea were exceedingly abundant at
both Hakel and Hajula.   The specimens are nearly always
found in a contorted position.   Pseudoberyx is known by three ‧
species from Hakel.   They are short-bodied, high, and com-
pressed fishes, with large and pectinated scales.   *Diplomystus
brevissimus* is another small, elevated fish from Hakel and

Hajula, and it must have swarmed in those waters. Another species of the genus has been described by Cope from the Upper Cretaceous of Brazil; several species, by Leidy and Cope from the Eocene of North America; and another, from the Oligocene of England, by Newton. To-day species are living in the fresh waters of Chili and New South Wales.

The Dercetidæ form an extinct family of elongated fishes, most of whose members lived during the Senonian, but some of which flourished during the Turonian. Two species of Leptotrachelus have been described from Sahel Alma, one from Hakel, and now another is sent to us from Hajula. This is a species very eel-like in form, and has been called *L. serpentinus*. One species of the genus has been described by Cope from the Upper Cretaceous about Yankton, South Dakota, and with it another related form, *Triænaspis virgulatus*.

The Enchodontidæ were numerous during the whole of the Upper Cretaceous. A. S. Woodward regards them as having as their nearest living allies the deep-sea families Odontostomidæ and Aleposauridæ. The enchodonts were undoubtedly predaceous fishes, having long fang-like teeth in their jaws and a huge gape. Five species come from Hakel, four from Hajula, and three from Sahel Alma.

Another interesting family of fishes which have come down the ages to our day from probably the Lower Cretaceous is the Myctophidæ, usually called the Scopelidæ. In our time they are fishes which live in the open sea, many of them being inhabitants of the deep waters, and many possessing phosphorescent organs. Figures and descriptions of many of the living forms may be found in Goode and Bean's *Oceanic Ichthyology*. At Hakel there have been collected eight species; at Hajula, seven, and at Sahel Alma, eight. While most of the species found at Hajula occur also at Hakel, none found at these places have yet been collected at Sahel Alma. Four new species come from Hajula, two of which come likewise from Hakel; and one new and rather small species, *Osmeroides ornatus*, also comes from Hakel. Osmeroides is used here in the sense in which it was originally employed by Agassiz and in place of the latter proposed name, Sardinioides. In the place of Osmeroides,

applied to a genus of Elopidæ, the present writer prefers to use the name Holcolepis. How much confusion might have been avoided had the latter name been employed for the elopid genus as soon as it was discovered that *Osmeroides lewesiensis* was not congeneric with *O. monasteri*! Specimens of a Nematonotus of unusually large size and having a greatly elongated first dorsal ray are referred to *N. longispinus* (Davis).

Eels are proverbial for their lubricity, but many of them were caught in the net formed by the sediments of the Senonian ocean. Davis had already in 1887 described from Hakel a little species which he called *Anguilla hakelensis*, but which Woodward refers to his genus Urenchelys. This author has likewise been so fortunate as to find another species of the genus in the Turonian of England. It is the oldest known eel. He describes also a third species from Sahel Alma. The species of the genus are shown to have about one hundred vertebræ and a caudal fin which is distinct from both the dorsal fin and the anal. The present writer has named a fourth species from a specimen collected at Hajula.

Besides these representatives of the family Anguillidæ, the writer has found two species which present most of the characters of Urenchelys, but which are peculiar in possessing well-developed ventral fins, a new feature in eels. This character brings the Apodes into closer relation with the other bony fishes. The species are regarded as forming a new genus, Anguillavus. the type of a new family, Anguillavidæ. One of the species, represented by a complete skeleton six inches long, from Hakel, and a fragment from Hajula, has been named, in honor of a worthy woman, *Anguillavus bathshebæ*. A larger species from Hajula has been christened *A. quadripinnis*. Besides ventral fins, this species seems to have had a row of enlarged scales on each side of the body, perhaps along the lateral line.

Still another eel hails from Hakel. It has been very slender, much elongated, and apparently without a fin of any description ; but the feature which most strikes our attention is the structure of the vertebræ. Throughout the length of the body, from the head to the tail, each vertebra resembles, not the ones adjoining it, but the second one behind it or in front of it. This

condition appears to be much like that found in the tail of Amia, and the writer explains it in the same way. The species is called *Enchelion montium,* the type of the new family Encheliidæ.

The remaining fishes are regarded as belonging to the order Actinopterygii, or Percomorpha. In these the dorsal and anal fins are usually wholly or partly spinous and the ventral fins are brought forward to beneath the pectorals. The order contains the most highly developed fishes. The Berycidæ, yet represented by some marine and mostly deep-sea forms, appear to have been very abundant during the Upper Cretaceous. A single species is known from Hakel, two from Hajula, and a dozen from Sahel Alma. These data appear to argue that the latter locality is at a higher level than either of the others. A new species of Pycnosterinx, *P. levispinosus,* is described by the author from Hajula. It is a small, compressed species, about an inch and a half in length, deeper than long, and with a steep front.

Three species of the genus Omosoma are referred provisionally by Woodward to the Stromateidæ, a family represented on our Atlantic coast by the butter-fishes and harvest-fishes. The three species are found at Sahel Alma only. Other genera supposed to belong to the same family are described from Westphalia and the south of England.

From Hakel and Hajula there have been obtained three species of Aipichtys, a genus placed by Woodward in the family Carangidæ. One of these species is a new one from Hajula.

The Cretaceous fishes of the families just mentioned, the Berycidæ, the Stromateidæ, and the Carangidæ, with their spiny fins, their thin and often ctenoid scales, their complete vertebræ, their thoroughly ossified skeletons, and their thoracic ventrals, form a strong contrast with the Semionotidæ, the Pycnodontidæ, and even the Chirocentridæ, which formed the greater part of the fish-fauna at the beginning of the Cretaceous period.

It is remarkable that no vertebrates, except fishes, have been found at Mount Lebanon. In the collections examined by the writer, not a scrap of any reptile has been detected. Ichthyosaurs had indeed reached the evening time of their existence. There were doubtless plesiosaurs swimming the deep, and we

might expect to find some trace of them in the Mount Lebanon
rocks.   There were certainly mosasaurs haunting the shores and
venturing out on the waves.   We should hardly expect to meet
with remains of dinosaurs, for these either stalked about on the
land or wallowed in the swamps of lakes and rivers.   Unless the
conditions were peculiar, we might anticipate finding bones of
turtles and crocodiles, possibly of pterodactyls.

It appears probable that the deposits of the Mount Lebanon
district were laid down in deep water and at a considerable dis-
tance from any shores.   The fineness of the materials of the
rocks favors this view.   The large numbers of Myctophidæ and
Berycidæ found there, seem to indicate that the depths were
considerable.   The presence of so many sharks and rays is not
opposed to this view, as may be learned by an examination of
the lists of fishes in Goode and Bean's *Oceanic Ichthyology*.

In case the deposits were made in deep water and at a con-
siderable distance from land, few reptiles would be entombed in
them.   Most of these animals probably found it more profitable
and more comfortable to remain near the shore.

Dana regarded the Niobrara deposits of Kansas, which have
furnished so many fossil fishes, as nearly equivalent to the Turo-
nian of Europe.   This was the opinion held by Cope also.   A
comparison of the Kansas fishes with those of the Turonian
and Senonian confirms this opinion.   Comparatively few of the
genera of Kansas fishes are found in the Senonian of Europe or
Syria.   On the other hand, about a dozen genera from Kansas
are represented in the Old World Turonian.

In 1878 (*Bull U. S. Geol. Surv.*, vol. 4, p. 67), Cope described
seven species of fishes which Hayden had collected in what is
now South Dakota.   No definite statement was made regarding
the locality ; but, written on the blocks of soft limestone bear-
ing the types, the present writer has found the word " Yankton."
This no doubt indicates approximately the locality whence the
fishes were derived.   Of these fishes, two species belong to
Leptotrachelus and one to Triæaspis, a genus close to Lepto-
trachelus.   Of other known species of the latter genus, all are
found in the Senonian, although one occurs in the Turonian
also.   One species from Yankton belongs to Spaniodon.   The

other three species of the genus are from Sahel Alma. Three
of the species from Yankton belong to Leptosomus. Two
other species of Leptosomus are known from Westphalia and
two from Mount Lebanon. Cope supposed that these fishes
were obtained in the Niobrara deposits; but, judging from their
close relationships with Mount Lebanon forms, it appears highly
probable that they came from a higher horizon, probably the
Pierre. It is a matter of considerable importance that some
geologist in that region should explore these beds. There
appear to be great numbers of the fishes, since on one block
about six inches square there are three of Cope's types and
one on the opposite side. The reader will find a figure of this
block on Plate 5, of volume 19 of the *Bulletin of the American
Museum of Natural History*.

AMERICAN MUSEUM OF NATURAL HISTORY.
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ON THE OSTEOLOGY AND SYSTEMATIC POSITION OF THE KINGFISHERS.
(*HALCYONES*.)

R. W. SHUFELDT.

BY FAR one of the most useful contributions to the recent literature of ornithology is the work entitled "*A Hand-List of the Genera and Species of Birds*," by R. Bowdler Sharpe, Three volumes have already been issued, while the fourth and last one is now passing through the press.

This work presents us with a hand-list of the species and sub-species of the birds of the world brought fully up to date. The "Systematic Index" is practically a classification of the class Aves, and in fact is Sharpe's taxonomy of birds, and is therefore one of great value and worthy of our closest study. It also takes into consideration the fossil forms of birds, and the distribution of all forms. Among other Orders enumerated, we find in Volume II of the "Hand-List" Order XXIX,— the Coraciiformes, which is subdivided into fourteen sub-orders created to contain a great many different kinds, and very differently affined, birds. These are as follows :— (I) Steator-nithes, (II) Podargi, (III) Leptosomati, (IV) Coraciæ, (V) Halcy-ones, (VI) Bucerotes, (VII) Upupæ, (VIII) Meropes, (IX) Momoti, (X) Todi, (XI) Caprimulgi, (XII) Cypseli, (XIII) Trochili, and (XIV) Colii. These suborders are duly divided into their families and other minor divisions. There is no intention of discussing in full this arrangement here, and the sequence of the suborders is given only to show the position assigned the Halcyones or the kingfishers, the group which is the subject of the present contribution. It is now more than thirty years since Sharpe published his famous monograph on the kingfishers, and it remains a classic in the literature of ornithology. In it the family Alcedinidæ was divided into nineteen genera, created to contain the 125 species described

in the memoir. Of these a subfamily division was made, the line being drawn between the insectivorous Daceloninæ, with 14 genera and 84 species, and the piscivorous Alcedininæ, containing the balance of the group. Now as will be seen, the Halcyones are placed between the Coraciæ on the one hand, and the Bucerotes on the other, a long ways removed from such forms as the Galbulidæ or jacamars, the Buccones, and the ground cuckoos, (Geococcyx), birds that appear in widely separated and entirely different orders.

The Halcyones in the " Hand-List " we find still to be divided into the two subfamilies Alcedininæ and the Daceloninæ, the first still containing five genera, and the last by an increase of one, now containing fifteen. The number of species, however, have been increased from the 125 enumerated in 1870 to about 200, or in other words there have been about 75 species of Kingfishers described within the last thirty-two years. A knowledge of their anatomy, however, has by no means kept pace with this remarkable discovery of new and undescribed forms.   The habits of the various kinds of kingfishers are described with greater or less detail in Sharpe's monograph, as well as the plumage and external characters, and as highly important as this is for an understanding of their affinities, it cannot be properly touched upon in this paper which deals with the osteology.   North America is extremely poor in kingfishers, as we find but two species and a subspecies of the genus Ceryle (*C. alcyon, C. torquata, C. a. septentrionalis*), given in the last A. O. U. " Check-List."   Australia, Africa, and the East Indies claim the greatest number of forms, but their distribution is extremely unequal, when taken as a whole, in so far as other countries are concerned.

In studying the osteology of such species as I have been able to obtain, I have taken special care to keep before me the geographical distribution of the family, the remarkable variations of the plumage, the beaks, and particularly the feet and other external structural characters; also similar data of the species representing other families of birds which avian anatomists from time to time have considered near relatives of the Halcyones. I have also had in mind, during my researches, the notes of the

various species, their habits, and their nidology, all of which has been done in order to avoid any biased opinion I might otherwise arrive at on any particular point, where the osteology alone had come to influence me in the formation of an opinion.

It is eighteen years ago since I have been engaged with the osteology of the kingfishers, when I published a brief illustrated memoir on the "Osteology of Ceryle alcyon," which appeared in the *Journal of Anatomy*, (Vol. 18, London, 1884, pp. 279–294), and yet it can be said with great truth that we stand much in need of a thorough investigation of the general structure of the Halcyones. Avian taxonomers and anatomists are not unanimous on the systematic position of the kingfishers, and still less so on their relationships with other groups of birds.

Some thirty years ago Cunningham contributed a brief notice of some of the anatomical points of the kingfishers (*Proc. Zool. Soc.*, 1870, p. 280), and for various views upon the taxonomy of the Halcyones and their affinities one should consult Wallace, (*Ann. Nat. History*, ser. 2, Vol. 18, pp. 201–205.): Eyton (*Contrib. Ornithology*, 1850, p. 80.) : Huxley (*Proc. Zool. Soc.* 1867, p. 467.) : Coues (" *Key to N. Amer. Birds*," rev. ed. p. 469, 1884.) : Fürbringer (*Untersuchungen z. Morph. u Syst. der Vögel.* Amsterdam, 1888, pp. 1555–1567) : and the Monograph of Sharpe already cited.

According to Huxley's classification, the kingfishers (Alcedinidæ) belong to the Desmognathæ, they forming a family of a third group out of four of the division designated as the Coccygomorphæ. He associates with them the Bucerotidæ, Upupidæ, Meropidæ, Momotidæ, and the Coracidæ ; and he also believed that they approached the Pelargomorphæ in their structural characters.

Newton tells us with great truth that " it is to be regretted that hitherto no light has been shed by palæontologists on this interesting subject, for the only fossil referred to the neighborhood of the Family is the *Halcyornis toliapicus* of Owen (*Br. Foss. Mamm. and Birds*, p. 554) from the Eocene of Sheppey — the very specimen said to have been previously placed by König (*Icon. foss. sectiles*, Fig. 153) in the genus Larus. (*Dict. of Birds.* 1893, Pt. 2, pp. 488–489). In the

same excellent work, and in the same article (" Kingfisher "),
Newton further states that "the common Kingfisher of Europe
is the representative of a well-marked family of birds, the *Alcedi-
nidæ* or *Halcyonidæ* of ornithologists, which is considered by
some authorities to be closely related to the *Bucerotidæ*; but
the affinity can scarcely be said as yet to be proved ; and to the
present writer there seems to be at least some ground for believ-
ing that a nearer alliance is to be found in the *Galbulidæ*,
Momotidæ, *Meropidæ*, and perhaps some other families —
though all may possibly be discovered to belong to one and the
same larger group."

The Halcyoniformes of Fürbringer form one of the suborders
of his order Coraconithes, and he divides them into three groups
(gens) *viz.*, the Halcyones, the Bucerotes, and the Meropes.
In the first-named we find but one Family (*sensu latiori*), the
Alcedinidæ, and this he divides into two others (*sensu stric-
tiori*), the Halcyonidæ, and the Alcedinidæ.   The Bucerotes
contain the Bucerotidæ and the Upupidæ, while the Meropes
contain only the single family Meropidæ.

In his *Manual of North American Birds* Robert Ridgway
places the family Alcedinidæ, together with the Cuculidæ, Tro-
gonidæ and Momotidæ in an Order Coccyges, but in differentiat-
ing the kingfishers gives a very slender array of characters, and
no structural ones.   (Phila. 1887, pp. 271–279.)

It is an interesting fact, although we have as yet but little
knowledge of the habits of the jacamars (Galbulidæ), that at
least some of the South American species secure their insect
food after the manner of some of the Daceloninæ, and that fur-
ther they make their nesting holes in marl-banks, thus agreeing
with the nidification of some of the kingfishers (Ceryle).

Newton is not alone among ornithologists in the belief that the
kingfishers are in some way more or less related to the jacamars
(Galbulidæ) and the bee-eaters (Meropidæ).   I believe it was
the naturalist Lesson who named one genus of jacamars, Jaca-
maralcyon, and another Jacamerops.

It is perfectly safe to say at the present writing that there
are no two avian classifiers who agree exactly on the question
of the relationships of the kingfishers, while on the other

hand, with others there exists the greatest possible variance in the matter of opinion on this subject. No two classifiers of birds would today agree as to the place of the Halcyones in the system, or would award them the same place in any scheme of classification. A unanimity of opinion can only be arrived at upon this point when the morphology and complete life-histories of all the forms are known, and have been compared and intercompared. As it is we are a long way from any such decision, and in fact we know very little of the anatomy of any of the kingfishers, the jacamars, the bee-eaters, the cuckoos, the trogans, the hornbills, the toucans, the hoopoes, and a dozen other families more or less related. This being the case, I must believe that any little contribution to the anatomy of any of the birds in question, will in time prove to be useful, and it is therefore with less hesitation that I bring forward here what little I have accomplished in the osteology of the Halcyones, not that I think that any part of it will completely settle any particular taxonomical point at issue, but that it may help to do so, when our knowledge in these matters becomes wider than it is at the present time.

In studying the osteology of the Halcyones I have carefully examined the skeletons of the following species of birds, and compared the characters they have presented with great thoroughness and detail.

1. *Ceryle alcyon*, belted kingfisher.   North America.
2. *Ceryle a. septentrionalis*, texas kingfisher.   Texas to Panama.
3. *Alcedo ispida*, Europe and many parts of the east.
4. *Geococcyx californianus*, road-runner.   Mexico and parts of the western United States.
5. Various cuckoos of the genera Coccyzus, Cuculus, Crotophaga, and others.
6. *Dacelo gigas*, Australia (skull).
7. Several of the Meropidæ.
8. *Steatornis caripensis*, Northern S. Amer. and Trinidad.
9. Trogan (several species).
10. Bucerotidæ (several species).
11. *Nyctiornis amicta*, Borneo.

12. Galbulidæ.

13. Trochili, many species.

14. Cypseli, various species.

15. Momotus.

Also incidentally the representative of several other groups, as the woodpeckers, Caprimulgi, and the toucans.

I am indebted to the United States National Museum for the loan of some of the material used in the preparation of the present memoir, and to that institution my thanks are due, as they are to Mr. F. A. Lucas for the loan of the skeleton of *Alcedo ispida* from his own collection. For the trogan skeletons I have pleasure in thanking Dr. Sclater, late Secretary of the Zoölogical Society of London; and the skeletons of Geococcyx, Mr. Herbert Brown of Yuma, Arizona. A number of the swifts and goatsuckers were kindly sent me by Mr. Jno. H. Sage of Portland, Ct., Mr. Gerrit S. Miller, Jr., of the U. S. National Museum, and Dr. A. K. Fisher of the U. S. Dept. of Agriculture. Many humming-birds and much of the other material has been supplied me by Messers F. Stephens, H. K. Coale, Luther N. Rossiter, H. W. Henshaw, J. G. Parker, E. M. Hasbrouck, and others,— to each and all of whom I desire here to return my thanks. Not a few of these specimens, now types of descriptions, are in the collections of the British Museum, and the Royal College of Surgeons of England.

With this preliminary introduction I am now prepared to pass to the consideration of the comparative osteology of the kingfishers (Alcedinidæ) employing primarily for this purpose the skeletons of specimens of *Ceryle alcyon*, *Ceryle cabanisi* and *Alcedo ispida*. These I will not only endeavor to carefully intercompare, but in turn, compare them with the skeletons of the various species and material set forth in the above list.

In my conclusions I shall have something to say regarding the relationships of the Halcyones to other groups of birds.

The Skull. — By referring to the figures, herewith presented, illustrating the skeleton of our common kingfisher (*C. alcyon*), it will be noted that the superior osseous mandible of Ceryle is considerably longer than the remaining part of the skull, being in fact a three-sided pyramid, with a broad base and sharp-pointed

apex. A very perfect cranio-facial hinge joins this structure to the cranium, and the tomial edges are sharp and slightly raised above the level of the nether aspect of this mandible. This skull is strongly desmognathous, and the rhinal chambers are quite filled in by the spongy mass of the bulky maxillo-palatines. Through this the parial subtubular narial passages run, and they terminate externally upon either side, as rather elongated, broadly spindle-shaped narial openings. Just to the rear of the posterior border of either one of these latter there is to be found a small circular foramen leading into the nasal passages just referred to, a character seen also in *C. cabanisi.* The external narial apertures are separated by a complete, rather thick septum narium, while in *Alcedo ispida* this partition is pierced by an oval foramen, at about its centre, and in this species the foramina described in the last sentence are absent.

The culmen, which forms one angle of this mandibular pyramid, is rounded ; while the side that forms a good share of the roof of the mouth is flat, marked its entire length by a small, deep, median groove, that exhibits impressed venations branching from it upon either side. At the hinder end of this groove a pair of small foramina are seen (Fig. 2, *3*).

We find this mandible in Ceryle, although having a very solid appearance from being closed in on all sides as it is, to be extremely light, having internally very much the same structure as in the hornbills, only rather coarser.

There is one other feature we notice on the superior aspect of the mandible in Alcedo that is absent in Ceryle ; this is a pretty-well marked groove, leading on either side from the anterior margin of the nostril back to the maxillary. It is shown in the drawing of this view of the skull here figured, from a specimen kindly lent me by Mr. F. A. Lucas of the United States National Museum (Fig. 1, *B, k.*).

Regarding the skull of Ceryle from above, we find the superior margins of the orbits sharp and regular, and separated from each other by the smooth, rather broad surface of the frontal region. This is slightly indented longitudinally by a shallow median groove that traverses the cranium from the transverse fronto-maxillary line, through the parietal portion. Here the

surface is raised, on either side, into smooth rounded domes, that are less marked in *C. cabanisi*, and that are bounded behind by the prominent and projecting temporal fossæ. These latter are divided behind by a sharp median ridge (see Fig. 2). All these features, though present in Alcedo, are far less noticeable, while the median ridge tends to merge into the surrounding surfaces. This is completely effected in the skull of such a form, for instance, as Geococcyx, where the temporal fossæ are
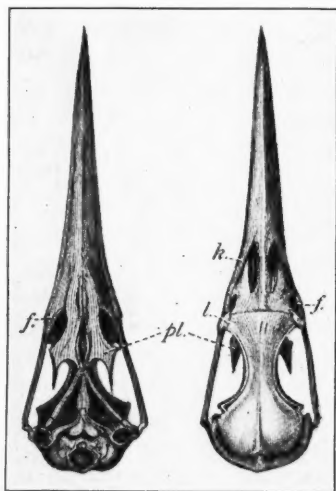
Fig. 1.—Superior (*A*) and inferior (*B*) views of the skull of *Alcedo ispida*; *l*, lacrymal; *pl*, palatine; *k*, inter-naso-maxillary groove on the mandible; and *f*, the maxillary. Natural size, after Shufeldt, *Jour. anat. Phys.* Vol. XVIII, 1884.

well separated, and the median ridge has become a broad surface, indistinguishable from the general superficies of the cranial vault. Holding a mid-position between these two conditions, we find an example in the skull of *Coccyzus americanus*, where the fossæ approach each other again.

Ceryle has its occipito-basicranial region circumscribed, and its plane faces posteriorly and only slightly downwards, much

as we see it in the skulls of some herons. The subcircular
foramen magnum is of fair size, and the condyle comparatively
small. Anterior to it the basitemporal space is limited, while
the usual groups of foramina are to be seen upon either hand.
There is also a groove leading up on either side of the foramen
magnum, that terminates in a minute opening on the not very
elevated supraoccipital prominence. The superior limiting mar-
gin of the occipital area in Ceryle is very sharp, while in Alcedo
and Geococcyx, where the same characters first enumerated are
present, this boundary is more rounded.

Viewing the skull of either *C. alcyon* or *C. cabanisi* laterally (Fig.
2), the unusually deep temporal fossa is again brought to our
notice, occupying much of the space behind, terminating only at
the superior margin of the large and very open ear cavity, and
allowing but just enough surface for the lodgment of the head
of the quadrate.

It has above it a. flattened squamosal process, which is sepa-
rated by a shallow concavity, still more anteriorly, from a feebly
pronounced post-frontal projection. The ali-sphenoidal wall
bulges forward in the form of an elevated dome, a feature
characteristic also of Alcedo. Above, the thin and horizontal
frontal affords the orbit an ample roof, this bone being carried
forward to join with the extensive surface of the superior por-
tion of the large *lacrymal*.

Viewed from above, this latter bone (Fig. 2) presents an
oblong surface with slightly rounded angles. Its infero-anterior
margin makes a close articulation with the nasal in front and
the frontal above, rather more than one third being devoted to
the first and the remainder to the latter bone. There is thrown
down from beneath this superior oblong plate of the lacrymal
another plate, the connection being a somewhat constricted
neck, which forms the greater part of the anterior wall of the
orbit. This plate is highly pneumatic, bulbous, and has a
smooth surface with a light spongy interior ; its shape is square,
with rounded angles. Its outer portion below rests upon the
horizontally expanded maxillary, while its inner and upper angle
has wedged into it a small oblong process that is developed from
the ethmoid : it is the pars plana. Above, they embrace a

large subelliptical foramen, through which, in life, the nasal nerve and vessels pass.   This inferior plate of the lacrymal is much larger than the superior, and is roughly placed at right angles to it.

Agreeing with *C. alcyon* and *C. cabanisi*, we find in *Alcedo ispida*, the form of the lacrymal and its articulations, substantially the same.   It differs principally in being thicker from before, backwards, and the pars plana, which in this kingfisher is triangular, meets it about the middle of the inner border rather than at the superior and inner angle, as it does in Ceryle.   In Geococcyx, the superior plate has moved down on the margin of the orbit nearer the maxillary, articulating almost exclusively with the nasal.   This change nearly does away with any distinction between an inferior and superior plate, the two having run together in nearly the same plane.

The ethmoid here develops a very large pars plana, and the lacrymal is so twisted to pass down in front of it, the former really forming the anterior wall of the orbit.   In *Coccyzus americanus*, the pars plana, is very extensive, and forms the entire inter-orbito-rhinal partition, while the lacrymal barely articulates with it, it being a light bone, having very much the form we found in Colinus.

One large vacuity is found in the interorbital septum in *Ceryle alcyon*, as shown in Figure 2.   This has the appearance above of being divided in two, by a very narrow isthmus of bone, in Alcedo, but we find this deception due to the large foramina for the exit of the nasal nerves from the brain-case in this bird, these openings being exceedingly small in Ceryle.

To return to the latter we find that the quadrate presents little or nothing that is peculiar.   Its orbital process is sharp and spine-like, projecting into the orbital space, though overshadowed by the bulging wall of the alisphenoid above.   This process of the quadrate is remarkably stumpy and short in Alcedo, while it is broad and flat in Geococcyx and Coccyzus, where it almost rests against the posterior wall of the orbit.

Upon the inferior views of the skull of Ceryle, we observe the anterior extremities of the palatines to be broad, horizontally flattened and thin plates.   They are separated from each other by

an interval of about two millimeters, and merge beyond into the bony roof of the mouth already described. The interval between their anterior ends is continued backwards to a point well within the articulation of the heads that articulate with the pterygoids. Near their inner margins, posteriorly, quite a large foramen exists in each, which is a constant character. Opposite the pars plana of the ethmoid in Ceryle, each palatine throws up a triangular plate of bone to project freely into the rhinal space. The postero-external angles of these bones are truncate, a feeble spine being produced near the middle in *Ceryle alcyon*, a character better marked in *C. cabanisi* while in *Alcedo ispida* this character is developed as a spine-like spur, and is very conspicuous.

This feature is also present in *Dacelo gigas*, while in Merops the long and slender palatines are devoid of any postero-external elongations.[1]

In Ceryle the inner margins of the posterior moieties of the palatines always fuse together, and this fusion is carried back as far as the pterygoidal heads, which it includes.

In my specimens of *Coccyzus americanus* there are no spine-like projections from the postero-external angles of the palatines, but the angles in question are distinctly defined, differing in this respect from *Cuculus canorus*, where "the palatines are rounded off postero-externally" (Huxley). This is the case also in the skulls I have at hand of Geococcyx, but Huxley found them to be distinctly indicated in the specimens he examined of this bird, so here this character may vary perhaps with the age of the individual.

I find no vomer in any species of Ceryle, and in this it agrees with others of the group, for we know "in Kingfishers and hoopoes there is no vomer."[2] Geococcyx has a small vomer. Again, in our kingfishers, the pterygoids are very long and straight, their distal extremities having on their outer sides little horizontally flattened and projecting triangular processes, inconspicuously developed in some specimens, and entirely absent in Alcedo, Geococcyx, and Coccyzus. None of the forms just mentioned

[1] See Fig. 29, Huxley's "Classification of Birds, etc." *Proc. Zoöl. Soc.* 1867, p. 447.

[2] Parker, W. K. and Bettany, G. T. *Morphology of the Skull*, p. 264.

possess basi-pterygoid processes, and the pterygoids in the ground cuckoo are very short in comparison with the great length of the skull, being somewhat shorter than they are in Alcedo.

In Ceryle the maxillaries are long and broad, being horizontally expanded plates passing, on either side, into the extensively developed maxillo-palatine masses anteriorly, which nearly
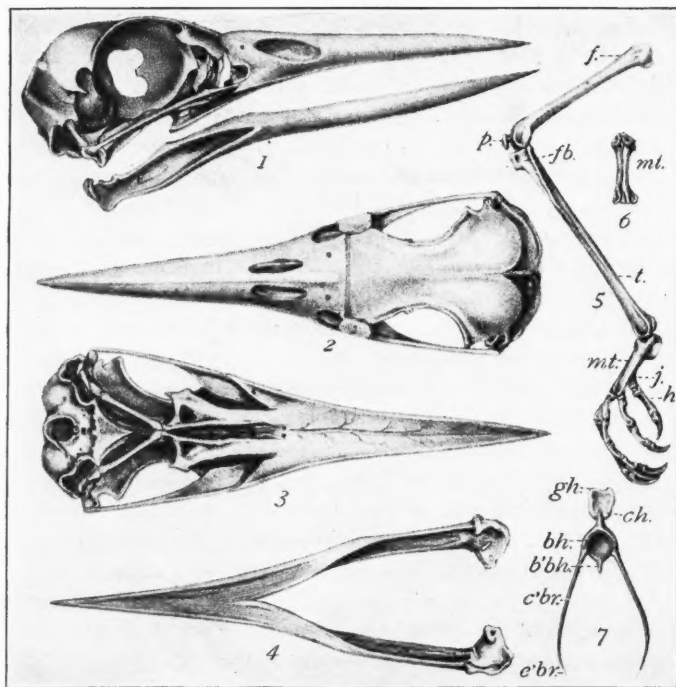

FIG. 2.—*1.*— Right lateral view of the skull and lower mandible of *Ceryle alcyon*: *l*, lacrymal; *nf*, nasal foramen; *ns*, nasal septum; *q*, quadrate; *pg*, pterygoid; *pl*, palatine; *m*, maxillary.—*2.* Superior view of the same skull, lower mandible removed.—*3.* Basal view of the same skull, lower mandible removed.—*4.* Superior view of the lower mandible of *Ceryle alcyon.*—*5.* Left pelvic limb of *Ceryle alcyon*: *f.* femur; *p*, patella; *fb*, fibula; *t*, tibio-tarsus; *j*, hallucial metatarsal; *h*, phalanx of hallux; *mt*, tarso-metatarsus. —*6.* The tarso-metatarsus, *mt*, in front view, from same limb.— *7.* The hyobranchial apparatus of *Ceryle alcyon*; viewed from above: *gh*, glossohyal; *ch*, cerato-hyal; *bh*, first basi-branchial; *b'bh*, second basi-branchial; *c. br*, cerato-branchial; *e. br*, epibranchial. All figures somewhat less than natural size, and reduced in the same proportion. After Shufeldt, *Jour. Anat. & Physiol.* Vol. 18, 1884.

fill up the forward part of the rhinal chamber (Fig. 2). In Alcedo this expansion is not particularly noticeable, while in other respects the arrangement of their parts is the same.

Alcedo also differs from the various species of Ceryle in the manner in which the quadrato-jugal bar articulates with the quadrate. In Ceryle it is received into an articulating socket on the outer side of the bone in question, while in Alcedo it meets it much more anteriorly, though somewhat laterally.

Passing to the base of the skull, again, we must note how small is the anterior aperture of the Eustachian tubes, and observe the sharpened lower border of the sphenoidal rostrum.

The form of the lower mandible is well shown in figures 1 and 4. It does not essentially differ in *Alcedo ispida*. Both of these birds sometimes have the ramal vacuity spanned across with a thin plate of bone, which may be pierced by a minute foramen. Sometimes in *C. alcyon* the ramal vacuity is nearly fitted in by this plate. Among the cuckoos this bone is very much more like the general form as we find it in the passerine types.

In Coccyzus a large ramal vacuity exists, and the internal angular processes are long and pointed, curving upwards, while rudimentary posterior angular processes here commence to make their appearance. In Ceryle the articular cups are deep; the mandible is pneumatic; the inturned articular processes are short and blunt, while the hinder ones are truncated. The bone is V-shaped with a very deep symphysis.

Nothing worthy of particular note rewards our examination of the internal aspect of the brain-case. The usual sclerotal plates are present in the eyes, and proportionate in size with other parts. The arrangement of the ear-cell is very simple; the delicate bony tie beams found in its interior, in so many birds, is here replaced by solid bone, pierced only by the necessary openings.

The hyoid apparatus (Fig. 2, 7) departs very markedly from ordinary birds. This is seen principally in the broad first basi-branchial (*bh*), with its slender, connate second basi-branchial (*b'bh*) reduced in this bird to a mere spine of no great length. The epi-branchials are very much shortened, and extremely delicate in structure, being tipped behind as usual with cartilage.

Behind, the glossohyal (*gh*) is broad and quadrilateral in outline, the cerato-hyals being scarcely discernible at its posterior and outer angles (*ch*).

The Axial Skeleton.— The vertebræ in Ceryle, when compared with many other birds of about the same size, are large, in comparison, with prominent processes. We find nothing to particularly distinguish the atlas. The plate closing in the neural canal of this segment above is oblong in outline, with a minute spine at each outer and posterior angle. The body is thick from before, backwards, so the shallow cup for the occipital condyle is never perforate, as it is in many birds. A large neural spine is found on the axis, and the diapophyses are elevated. Situated somewhat posteriorly, a neural spine, smaller than that of the axis, is found on the third vertebra, and this process diminishes in size as we proceed backwards, to disappear entirely on the ninth vertebra. The twelfth has a small one again, becomes larger still in the thirteenth, and in the next of the series appears very much like the elevated quadrate plates as seen in the dorsals. In the third vertebra the foramen found in the plate between the pre- and postzygapophyses, as a common avian characteristic, is here sometimes scarcely perceptible. But in this vertebra two other features arise — the cervical extremity of the vertebral canal, with minute parapophyses projecting from it on either side, and, secondly, the appearance of an hypapophysis beneath. In some of the leading cervical vertebræ after the third, usually the fourth, fifth and sixth, there is a bridge of bone, on either side, connecting the posterior margin of a parapophysis with the antero-external base of the corresponding postzygapophysis. This bridge becomes absorbed behind, in the sixth and may be in the seventh and eighth vertebræ, and then projects from the parapophysis simply as a spine-like process. The vertebral canal persists through the cervical chain to include the twelfth vertebra; in the thirteenth it is closed in by a very delicate little rib, consisting of but scarcely anything more than head, neck and tubercle. In the fourth vertebra the hypapophysis is but feebly developed, while the parapophyses are much stronger; these latter disappear in the twelfth vertebra. The carotid canal traverses the inferior aspects of the centre of the

fifth to the ninth vertebra inclusive ; while in the tenth, eleventh
and twelfth a median single plate reproduces the hypapophysis
once more.   This process is three-pronged in the thirteenth ;
bifurcate, with nearly horizontal limbs, in the fourteenth, which
latter decrease in size in the next, although the process length-
ens, — and thus it continues, as a rule, throughout the dorsal
series, being shorter only upon the last two.   In some specimens
of *C. alcyon* I have seen this hypapophysis quite rudimentary
upon the last dorsal vertebra, and in a specimen of *C. cabanisi*
(U. S. National Museum) I find these spines present, though
they are not very long, upon the two leading vertebræ of the
sacrum.   There is also at my hand a disarticulated skeleton of
C. alcyon, and in these two individuals, this one and the afore-
said skeleton of *C. cabanisi*, I find after careful count, rather a
remarkable difference in their vertebræ.   In the skeleton of *C.*
alcyon there are *nineteen* free vertebræ from the occiput to the
pelvis, whereas in the skeleton of *C. cabanisi*, there are but
eighteen.   Again, in the latter we find the first pair of free
riblets, (cervical ribs) on the *twelfth* vertebra ; a stronger pair
on the thirteenth ; and a free pair again on the fourteenth ; the
last ones have epipleural appendages upon them.   Now in the
skeleton of *C. alcyon*, the first free cervical riblets occur upon
the *thirteenth* vertebra ; a stronger pair is found upon the four-
teenth ; and finally, a free pair, with epipleural appendages,
upon the fifteenth.   In my paper upon the osteology of *C.*
alcyon in the *Journal of Anatomy* (London, 1884) I see that
the specimen whose skeleton I there describe, had the same
arrangement as the skeleton of the individual now before me
belonging to the collections of the U. S. National Museum.

That there is a variability in the number of vertebræ appears
from what follows ; — for I find that in my paper, first men-
tioned, I say of the dorsal series of ribs and vertebræ, in *C.*
alcyon that "The four dorsal vertebræ, with their ribs connect-
ing with the sternum, have nothing very peculiar to mark
them.   They freely articulate with each other, and develop
stumpy metapophyses on their transverse processes.   The unci-
form projections are not anchylosed with the ribs.   Two
pairs of ribs are suspended from beneath the ilia, belonging

to the antecedent vertebræ of the so-called "sacrum." The first pair have small unciform processes, their hæmapophyses articulating with these bones on the last dorsals in the usual manner; the last pair, which are very delicate in structure, vary exceedingly in length, and terminate in free extremities." Now the just-quoted description does not tally with what I find in the skeleton of *C. alcyon* from the U. S. National Museum, for in the first place in the sternum of that individual there are *four* articular facettes upon the *right* costal border and but *three* upon the *left*. The fault here, however, or this discrepancy seems to be due to some difference in arrangement at the fore end of the series, as the *left* costal process is longer, and has a suspicious looking spine *anchylosed* to it, at about the point where the leading costal rib ought to have had its facet. The *total* number of ribs in these two specimens of *C. alcyon* may, however, have been the same, while a difference only existed as to the number that connected with the sternum by costal ribs. This will not apply, though, to what we find in *C. cabanisi*, for here, although there are *four* dorsal pairs of ribs, supplied by the 15th, 16th, 17th and 18th vertebræ, only the three leading pairs connect with the sternum by means of hæmapophyses; the last pair failing thus to connect. Then, finally, there is but one pair of "sacral ribs," and their hæmapophyses are still shorter than the pair on the last dorsal ribs, and these sacral ribs are likewise without epipleural appendages, being the only pair that do lack them in this species. The arrangement of the ribs in birds cannot always be relied upon nor even that the same species always have the same number; but I cannot well account for the difference in the number of the cervico-dorsal vertebræ in these two kingfishers. The method of anchylosis of the pelvic bones with the sacrum sometimes has something to do with it, but apparently not here, for as near as I can count in the pelves of these adult birds, there appear to be *twelve* vertebræ in the pelvic sacrum of *C. alcyon*, and but *eleven* in *C. cabanisi*. This evidently does not help, for to satisfactorily account for the difference in question, the count should stand the other way.

Aside from the number of vertebræ in the pelvic sacrum, how-

ever, the pelves in these two species of kingfishers are very much alike. In both, the pelvis is broad and shallow. The ilia are widely separated from each other throughout their extent, and, anteriorly, the sacral crista is low and inconspicuous. Interdiapophysial parial foramina occur the entire length of the pelvis, being very small, or sometimes only closed in at an area constituting the central portion of the bone. Individual specimens differ much in this respect, they being nearly absent in
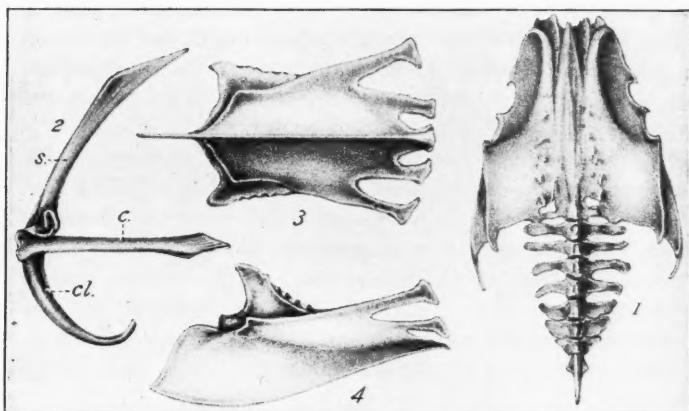

Fig. 3 — *1.* — Pelvis and coccygeal vertebræ seen from above in *Ceryle alcyon.* — *2.* Left lateral view of the shoulder-girdle of *Ceryle alcyon*; bones articulated as in life; s, scapula; c, coracoid; cl, clavicle. — *3.* Lower view of sternum of *Ceryle alcyon*; and shows very well how far the carina in the curiously shaped sternum of this Kingfisher projects beyond the body of the bone. — *4.* Left lateral view of the sternum of *Ceryle alcyon.* Figures all drawn by the author, natural size after Shufêldt, *Jour. Anat. & Physiol.*, Vol. 18, 1884.

some (see Fig. 3). The superior surface of either ilium, anteriorly, is concaved, not extensive, looks upwards and outwards, and is especially characterized by a sharp, backward-turned process upon its outer margin. Viewed laterally, the pelvis appears very shallow; the pubis being a curved, slender rod of nearly uniform calibre that does not come in contact with the ischium above, for its entire length. It projects somewhat posteriorly. Upon this aspect a notch, triangular in outline, is seen to exist between ischium and ilium at their posterior borders. Antitro-

chanter is small, but the foraminal apertures, the acetabulum, the obturator and ischiadic apertures, seen upon this aspect, are of an average size.

Seen upon ventral aspect, we are to note, that usually but a single pair of parapophyses are sent out as supporting braces opposite the acetabulæ. The sacrum on this aspect exhibits, along its middle portion, a medio-longitudinal groove that is very striking even upon superficial examination; the centrum of the anterior sacral vertebra is very deep and sharp. Specimens of *C. alcyon* show *three* anterior sacral vertebræ that throw out lateral processes against the nether aspects of the iliac walls. *C. cabanisi* shows *four*. The pelvic basin is broad and capacious in both these kingfishers, being more so in the former species than it is in the latter.

The tail-vertebræ are seven in number, not including the rather small pygostyle. The three anterior ones usually have long and slender diapophyses, while these processes in the last four are broad and become gradually shorter as we proceed posteriorly. We also note that the last three caudal vertebræ develop bifurcated hypapophyses below, a character likewise enjoyed by the pygostyle.

The sternum in the representatives of the genus Ceryle is rather a curiously formed bone, and not only differently shaped from the sterna of ordinary birds, but differs to some extent among the several species. So far as I know, it is invariably four-notched in this group of kingfishers, the xiphoidal prolongations being dilated at their hinder ends, more especially the outer ones. Four facets for the hæmapophyses of the dorsal ribs are found on the superior aspect of each costal border, and beyond the anterior ones prominent costal processes arise.[1]

The sternal carina is somewhat shallow behind, gradually becoming much broader in front, where it protrudes considerably beyond the body of the bone (see Fig. 3). In *C. alcyon* its anterior margin is straight, while in *C. cabanisi* it is markedly concaved; and in both species it extends the full length of the sternum. Another difference is seen in the manubrial process,

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[1] I have already stated that in one sternum of *C. alcyon* examined, there were but three of these facets on the left costal border, and the usual four upon the right.

for in *C. alcyon* it may be said to be almost entirely aborted, whereas in *C. cabanisi* the supero-anterior angle of the projecting keel rears into quite a respectable manubrium.

The grooves for the coracoids do not meet in the median plane by at least a millimeter or more in the larger species, while we often find a pneumatic foramen present immediately in front, upon the antero-superior edge of the projecting sternal keel. Both these kingfishers, too, seem to possess a small, circular foramen of this character, in the median line, on the thoracic aspect of the body, just within the anterior coracoidal border. Our belted kingfisher also has minute apertures of this nature at the base of the interhæmapophysial pits along either costal border.[1]

Coming next to consider the bones of the shoulder girdle (Fig. 3) we find the scapula in *C. alcyon* to be rather broad, of nearly uniform width throughout, being obliquely truncated from within outwards for its posterior third. It has a conspicuous process, which, when the bones of this arch are articulated, extends in the direction of the head of the corresponding coracoid, having the furcula resting against its mesial aspect. *Ceryle cabanisi* has comparatively a narrower scapula, and its posterior end is more distinctly bent outwards. In it the coracoid

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[1] Before passing to the consideration of the shoulder girdle, and closing my description of the vertebral column and its attached bones, it is well to note an interesting point in the vertebræ of Ceryle which I believe was first demonstrated by W. K. Parker in his paper "On the Osteology of *Steatornis caripensis.*" (*Proc. Zool. Soc.* of Lond. Apr. 2, 1889; p. 175). In comparing the skeleton of Steatornis with our kingfisher (a specimen of which I had sent him), Parker says "In a New-World Kingfisher (*Ceryle alcyon*) the hinder dorsal centra make a great approach to those of Steatornis, without, however, being opisthocœlous." And again upon the same page. "The *sacral vertebræ* [of Steatornis] and the whole pelvis are very much like those of *Ceryle alcyon*,— the Kingfisher whose dorsals show a tendency to the opisthocœlous character, and have deep, concave-sided dorsal centra, with long, basally-dilated, inferior spines."

I have personally made this same comparison, and can confirm the points above noted by Parker, especially in the pelves of these birds, is the resemblance striking. Steatornis, however, lacks the peculiar process upon the outer free margin of either ilium, seen in the kingfisher, and upon ventral aspect it would appear that the parapophyses are not increased in size, length and strength, to act as braces opposite the acetabulæ, as they are in Ceryle. For the remainder of the skeleton in these two forms, the resemblance ends entirely, beyond the points just cited.

process, just described, does not reach the coracoid when the bones are assembled *in situ.* The coracoid is considerably dilated at its sternal end, with raised facet there on its posterior aspect for sternal articulation. Its shaft is straight, not stout, subcylindrical in form, and rather long. At its anterior end we note a large glenoidal facet, and the usual inwardly-crooked, tuberous head. A spiculiform, clavicular process, is to be seen at some considerable distance below this, upon the mesial aspect of the shaft. This is equally well-marked in *C. cabanisi,* a species having a coracoid after the pattern of that bone in the typical picivorous kingfishers.

Our belted kingfisher has an os furcula of the broad, — very broad U-shaped model — without a semblance of a hypoclei-dium. The bone is slender below, but the clavicular limbs gradually become broad, and much compressed laterally, as we proceed in the direction of either head. So that, viewed as a whole, either clavicular limb may be said to be almost blade-like, with the free end, when articulated *in situ,* reaching back along the antero-mesial aspect of the corresponding scapular for some little distance. *Ceryle cabanisi* is peculiar in having a process developed upon the superior margin of either clavicular head, which, passing upwards and backwards, articulates with the tuberous head of the corresponding coracoid at a point situated at its antero-mesial aspect. I find no os humero-scapulare in any of these birds.[1]

The Appendicular Skeleton.— In the pectoral limb the humerus is the only bone possessed of pneumaticity ; — the pneumatic foramen being single, very open, and fills the entire base of the fossa. Its surrounding margins in *C. cabanisi* are thickened, and the fossa is markedly shallow. Proportionately, this bone is very long, — being but two thirteenths shorter than the bones of

[1] With respect to the method of articulation of the os furcula in *C. alcyon,* I find that in my above-quoted paper upon the osteology of that species I said that "In the articulated skeleton (Army Medical Museum, Washington, Section Comparative Anatomy, No. 155) it rests against the anterior border of the sternal keel at the junction of the middle and lower third."

This must be taken with caution, as it may not be invariably the case, and the skeletons in the institution referred to, are by no means to be relied upon. In *C. cabanisi* it does not thus rest upon the anterior carinal border.

the antibrachium.   Its radial crest is but moderately developed, and a deep valley is sculpt 'twixt ulnar tuberosity and humeral head.   In other respects this bone presents the usual characters found among birds generally.

The osseous tubercles for the quill-butts of the secondaries, found in many of the class along the shaft of the ulna, are here absent or very faintly perceptible in some specimens.   Both bones of the antibrachium in the well-developed limb of these kingfishers are as we usually find them in ordinary birds.   *C. alcyon* upon the superior aspect of the distal end of the radius, exhibits a single, deep groove for the guidance of tendons.   The two carpal segments are well apart from each other, thus affording quite an extensive share of the head of the metacarpus for articular surface for the ulna.   I find no small sesamoids, either at the wrist or at the elbow.   The index metacarpal, the main shaft of the carpo-metacarpus, develops at the proximal extremity of the shaft, the palmar aspect, the flattened process which is seen in other groups of birds.   It nearly reaches across to the border of the adjacent middle metacarpal, and this latter bone is distally longer than the metacarpal of the index, projecting slightly beyond it.   The expanded portion of the proximal phalanx of index finger is non-perforated and well-developed.

One phalanx is allotted to pollex digit, two to index, and one to medius, claws and spurs being absent in the manus of Ceryle.

Formerly, I believed the pelvic limb in the kingfishers was entirely non-pneumatic, but by examining far more extensive material, I am convinced that the femur may be pneumatic in many individuals.   The National Museum specimen (No. 18749) of *C. alcyon* is peculiar in this respect, for the right femur undoubtedly enjoys this condition, whereas the fellow of the opposite would, I think, be taken for a non-pneumatic bone.   For its remaining characters we are to note, that although the trochanter projects somewhat anteriorly, it does not rise above the summit of the shaft.   This latter is straight and cylindrical, being but very feebly marked by ridges or lines for muscular attachment.   An ordinary avian patella is present.

On the proximal and anterior aspect of the tibio-tarsus the pro- and ectocnemial ridges are but feebly produced: they are

best marked in *C. cabanisi*. An evident feebleness stamps the bones of the leg, that is when we came to compare them in size with other long bones of the skeleton. Kingfishers having weak pelvic limbs, we naturally find the skeleton of the parts likewise weak. Nowhere is this better seen in the limb of this bird, or birds of this group, than in the tarso-metatarsus and foot-skeleton. At the distal extremity of the tibio-tarsus of *C. alcyon* we find the antero-osseous bridge for the confinement of certain tendons to be situated very low on the shaft, indeed, it occurs immediately above the rather prominent condyles.

The fibula has but a slender spine of bone below the fibular ridge of the tibio-tarsus, and in some specimens I find even this missing. When this latter condition exists, *C. alcyon* has as short a fibula as any bird of its size, with which I am at present acquainted.

The tarso-metatarsus is less than a third as long as the shaft of the tibia (Fig. 6), the rather large free metatarsal for hallux thus being compelled to take a position in articulation very near the middle of the shaft of this bone. The "hypotarsus" is large in proportion, and exhibits a median groove, posteriorly, for the passage of tendons, and immediately anterior to it a single cylindrical perforation for the same purpose.[1] Distally, the tarso-metatarsus, has three well-developed trochleæ, either of the lateral ones being larger than the bigger one in the middle. The foramen for the anterior tibial artery is present, while at the proximal end of this bone in front we note a small protuberance for the insertion of the tibialis anticus muscle, as well as two small antero-posterior perforating foramina, placed close to each other side by side.

The digits of the foot possess the normal number of phalanges (2, 3, 4, 5), as they occur in the class. The basal joint of hallux is somewhat laterally expanded at its proximal end. With respect to the joints of the other toes, the three anterior ones, we note that the proximal joints have an articulatory movement nearly in the same subhorizontal plane, while careful examina-

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[1] This corrects a statement I made on this head in my paper "On the Osteology of *Ceryle alcyon*, quoted above. There are a few other slight inaccuracies I have taken the opportunity to correct in the same manner.

tion of the opposed surfaces of the bones composing the outer and middle toes, show the effect of their being so long strapped together in a common podothecal sheath, in the evident compression of the ridges and elevations usually found on these phalangeal bones in avian feet where the digits are free.

SYNOPSIS OF THE PRINCIPAL OSTEOLOGICAL CHARACTERS OF THE GENUS CERYLE OF THE FAMILY OF THE KINGFISHERS.

1. Superior mandible once and a half as long again as the cranium ; tapering and of a pyramidal form, flat upon its under side.
2. Septum narium complete.
3. Cranio-facial hinge quite movable (this is especially the case in the dried skull, after the quadrate and lacrymals have been removed).
4. Lacrymal large, with a superior and inferior portion.
5. Pars plana very small.
6. Large vacuity in interorbital septum.
7. Maxillaries very broad, horizontally flattened plates.
8. Maxillo-palatines large, subspongy, fused in middle line, nearly filling post-rhinal chamber.
9. Palatines broad, horizontal, with the postpalatine parts fused together in the middle line.   A large foramen pierces either postpalatine.
10. Pterygoids long and straight.
11. Crotaphyte fossæ deeply sculpt, and only separated by a crest posteriorly.
12. Lower margin of sphenoidal rostrum sharp.
13. Lower mandible V-shaped ; long deep symphysis ; articular cups deep, truncated behind, with stumpy inturned processes.
14. Hyoidean arches peculiar, with very broad basibranchial and cerato-hyal parts.
15. Nineteen cervico-dorsal vertebræ in *C. alcyon,* and only

eighteen in *C. cabanisi*, with a variable arrangement of the ribs.[1]

16. Vertebræ comparatively large; long hypapophysial processes characterize the ultimate cervicals and the dorsals. Centra of dorsal region laterally compressed, subopisthocœlous (Parker). Pneumatic. Neural canal large in middivision. Carotid-hypapophysial canal open. Seven caudal vertebræ and a pygostyle.

17. Pelvis broad and shallow; ilia widely separated from sacral crista, with a peculiar process on the outer free margin of either bone. Postpubic element long and slender, projects posteriorly, and is not in contact with ischium above. One pair of vertebral parapophyses thrown out as braces opposite the acetabulæ.

18. Sternum 4-notched behind, with carina projecting in front. Manubrium either entirely aborted or much reduced. Pneumatic.

19. Os furcula broadly U-shaped, slender below, broad above, where in *C. cabanisi* a peculiar process is developed extending to head of coracoid on either side. Coracoids long, and moderately slender. Scapula with conspicuous coracoclavicular process, the blade of the bone being narrow, longly truncated behind, and in *C. cabanisi* turned outwards for its posterior third.

20. Pectoral limb well-developed : humerus pneumatic : long. Process present on proximal end of index metacarpal, palmar aspect. Blade of proximal phalanx of index digit entire.

21. Lower part of pelvic limb feebly developed. Femur may or may not be pneumatic. Patella present. Fibula weak. Tarso-metatarsus very short, with its hypotarsus once pierced and grooved for tendons. Podal joints run 2, 3, 4, 5 respectively, feeble, and in the anterior toes somewhat laterally compressed.

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[1] This character needs further investigation, and it should be either confirmed or disproved.

Negative Characters.

(Ceryle.)

1. Vomer absent.
2. No basipterygoid processes.
3. No hypocleidium on os furcula.
4. Os humero-scapulare absent.
5. No prepubis on pelvis.
6. Claws not present on digits of manus (?)
7. Aside from patellæ, sesamoids not found in the limbs.

Further osteological comparisons, with notes on the position of the kingfishers.

My opinion upon the systematic position of the kingfishers is but a tentative one, for I have not examined all the material I could wish in order that I might render it more positive.   There are many forms of kingfishers in the world, and they vary much among themselves in their organizations.   The anatomy of these various species should be fully comprehended, and with this knowledge at our command we should fully investigate the structural economy of many forms of birds that we now suspect of being alcedine affines,— and it will only be when this is done that we will gain any correct idea of the subject.

As the present memoir shows, I have carefully looked into the skeletology of our two species of Ceryle.   Further, I have examined in connection with other extensive materials a skeleton of *Alcedo ispida*, and a skull of *Dacelo gigas*.   Skeletons of Coccyzus, Crotophaga, and Geococcyx have also been thoroughly compared, and I have compared skeletons of a jacamar, of Diplopterus, and one of the Meropidæ from Borneo, *viz.*: — *Nyctiornis amictus*.   Also, I have studied some of the skeletons of various Bucerotidæ and the Trogones, as stated.

We find the skeletons of the extremes of the insectivorous Daceloninæ and the piscivorous Alcedininæ to differ considerably in their characters, and I am of the opinion that it will be through a study of the osteology of the Daceloninæ that

we will eventually come to a knowledge of the kinships of the kingfishers with other groups of birds.

To me, it is not difficult to see the reason for Huxley's remarks when he said "*Alcedo* and *Dacelo* repeat the structure observed in *Geococcyx*, with minor modifications, and that "the *Alcedinidæ* [approach] the Pelargomorphæ" (*Proc. Zool. Soc.* 1867, pp. 447 and 467).[1]

Already I have committed myself to the belief that the Halcyones are most nearly related to the Galbulidæ. Still, I think so, but I likewise think that the osteological resemblances will best be seen when we come to compare the skeletons of certain jacamars with the more aberrant Daceloninæ.

The specimen of Jacamar (sp.?) now at my hand shows in its skull some characters that agree pretty well with the corresponding ones in the skull of *Ceryle cabanisi*, but as a whole the Jacamar's skull agrees equally well, and in some respects better, with the skull of Geococcyx. It differs from both in having an entire orbital septum ; in having a remarkably long post-frontal process, with a complete abortion of the squamosal process ; and in the supraorbital prominence being so conspicuous. Its pars plana and lacrymal most nearly approach Geococcyx, but its lacrymal is peculiar in the great definition of its external notch.

The osseous mandibles are most like the kingfisher's, while its palatines and its maxillo-palatines again remind us most of the same bones in Geococcyx.

It seems to lack a vomer, and this would again suggest Ceryle or perhaps some other more nearly related Kingfisher.[2]

With respect to the sternum, we remember that the fore-part of the carina in *Ceryle alcyon* and *Ceryle cabanisi* differ considerably in their form. Now, the fore-part of the sternum, the carina of the same, and the costal processes in this Jacamar, more nearly agree with what we see in these parts in *C. cabanisi* than do the same parts agree between the two kingfishers just

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[1] I can still see this, notwithstanding the fact that the postero-external angles of the palatines in Geococcyx are *not* produced as processes, as they are in Alcedo and Dacelo, and as Huxley thought they were.

[2] There are some points about the skull of this Jacamar that call to my mind the skull of certain of the Trochili.

mentioned. But in the jacamar the two notches upon either side of the keel are notably profound, and the xiphoidal prolongations very slender ; the inner ones not being in the least dilated at their hinder tips, while very handsome dilations characterize the ends of the outer pair. Now to make the sternum of *C. cabanisi* agree with the sternum of the Jacamar, we would simply have to deepen its notches to a similar extent, and the two bones would then be very considerably alike. Again the fore-part of the pelvis in the jacamar is quite after the order of the kingfisher, but the resemblance is lost when we see in the former how peculiarly the ilia and ischia are produced behind ; but here, too, this appears to be but an exaggeration of what we really see in *Ceryle alcyon*. Aside from the zygodactyle feet of the jacamar, we could easily select some very good characters, that seem to indicate that in the remainder of the trunk skeleton, and the skeleton of the limbs of this bird there is much more than a mere resemblance to the corresponding parts in the skeletons of our two North American kingfishers.

When we come to compare our skeleton of *Nyctiornis amicta* as representing the Meropidæ with the skeletons of the two species of Ceryle we have under consideration, we meet with still other characters that suggest inter-relationship for these two families, while Nyctiornis has some peculiar characters of its own. In principle, the arrangement of the bones of the palatal aspect of the skull, agree in Geococcyx, Ceryle and Nyctiornis, and I may say the resemblances are distributed with the most perplexing singularity.

On the whole the superior osseous mandible in Nyctiornis is more like what we see in Geococcyx than in either of our kingfishers, while the lower jaw possesses characters common to both, and is peculiar in not having even the vestige of a ramal vacuity, wherein it disagrees with both.

The lacrymal in Nyctiornis is very similar to that bone as it occurs in Geococcyx, but it is narrower, and not quite so tuberous ; the exceedingly small pars plana, however, agrees with Ceryle, and leaves in this bee-eater a great vacuity between lacrymal and pars plana, which opens into the rhinal chamber. Its interorbital septum is thick and practically entire ; this agrees with

the Jacamar, and differs with both the cuckoo and the king-
fisher.   The form of the occipital region of the cranium and the
deep and sharply-defined crotophyte fossæ of Nyctiornis agree
in many respects with Ceryle, but when we come to compare the
pterygoids and quadrates of our Bornean bee-eater with those
bones as they occur in *Ceryle cabanisi*, we are confronted with
decided differences.   In the kingfisher the orbital process of a
quadrate is almost a hair-like process, while it is broad and strong
in Nyctiornis.   Again, in the kingfisher the proximal end of the
pterygoid articulates with the mesial aspect of the inner mandib-
ular facet of the quadrate ; in Nyctiornis it articulates with a
facet situated directly between the orbital process of the quad-
rate and its mandibular condyle.   The mandibular sesamoid in
the bee-eater is unusually large, is moulded upon the quadrate,
and articulates with a special facet upon the angular extremity
of the jaw.

The post-palatines of Nyctiornis fuse together in the middle
line, and with the small, rod-like vomer of this bird, while the
postero-external angles of the palatines are angulated without
possessing a very distinct process.   The maxillo-palatines are
large and co-ossified across the middle space as in Geococcyx,
and they practically agree in these two species.   At the lateral
aspect of the skull in the bee-eater we observe the post-frontal
and squamosal processes to be rather small, and the zygomatic
bar transversely compressed, and vertically rather broad.   We
may add here that the skeleton of the hyoidean arches of the
kingfishers is peculiar, and is quite different from what we see
in the Meropidæ.   I have not examined it in the jacamars.

Passing to the remainder of the skeleton we find many points
of agreement between *C. cabanisi* and Nyctiornis.   Their ver-
tebral columns and ribs are essentially very much alike, and this
is strikingly the case with the pelves of these two birds.   In
their limbs and shoulder-girdles they also agree very well indeed,
but we find in Nyctiornis, on the other hand, a most remarkable
sternum.   This bone has a manubrial process quite like what
we see in the sternum of *C. cabanisi*, but it differs in having an
osseous mesial bridge thrown across from its posterior aspect to
the anterior border of the body of the sternum, and this bridge,

above, develops two lateral processes, one upon either side, while the coracoidal grooves are below it.   Posteriorly, this sternum is even more peculiar, for externally its xiphoidal portion shows two very deep lateral notches, with slender processes to their outer sides which have large dilated hinder ends, while internally, that is upon either side of the sternal keel, we find an elongated, sub-elliptical fenestra.   Either one of these fenestra have the appearance of being formed by the hinder end of what would have been the internal xiphoidal process, fusing with the posterior point of the mid-xiphoidal prolongation.

There are two points, that should be mentioned, perhaps, in the shoulder-girdle of Nyctiornis before closing my brief comparative remarks upon its skeleton, and one is the conspicuous expansion of the sternal end of either coracoid ; and the other, the fact that the outer aspect of either clavicular head has a modified, jutting shoulder upon it for articulation with the anterior aspect of the tuberous head of the corresponding coracoid.

There is evidently a hetero-kinship among Coccyzes, Halcyones, Meropidæ, Galbulidæ and undoubtedly other groups of birds, but we will know little of the nearness or the remoteness of these several affinities until the entire morphology and life histories of the several groups are worked out.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS AND DEATHS.

EDUCATIONAL GIFTS.

Alleghany College, $20,000 from Mrs. H. F. Ballantyne.

Armour Institute $150,000 from J. O. Armour.

Barnard College, $1,000,000 from Mrs. E. M. Anderson for the purchase of land.

Beloit College, $50,000 from Andrew Carnegie for library building.

Carthage (Ill.) College, a conditional gift of $145,000 from Henry Denhart.

Cleveland, Ohio, $250,000 from Andrew Carnegie for library purposes.

Colby College, $46,000 from various sources.

Columbia University, $2,000,000 from J. Pulitzer for a school of Journalism, $15,000 for scholarships.

Field Columbian Museum, a large sum (variously stated) from Marshall Field.

Hamilton College, $100,000 from Andrew Carnegie.

Harvard University, $50,000 from James Stillman for the hospital.

Illinois College, about $75,000 by the will of Dr. Hiram K. Jones.

Johns Hopkins University, $60,000 by the will of Mrs. Harriet Lane Johnston.

Kingfisher (Oklahoma) College, $25,000 from Andrew Carnegie.

Patterson, N. J., $130,000 for library building from Mrs. Mary E. Ryle.

Rush Medical School, $1,000,000 from various sources.

Syracuse University, one third the residuary estate of Mrs. Caroline S. Reid.

University of California, $500 from Mrs. A. S. Halliday for the library.

Vassar College, $13,000 and a new organ from various donors.

Wellesley College, $25,000 from Robert C. Billings.

Wesleyan University, $2000 by the will of Mrs. Henry F. Ackley.

Westwood, Mass., the greater part of the estate of Mr. H. O. Peabody, valued at $1,000,000, for a girls' school.

Williams College, $25,000 from Francis L. Stetson.

Winter Park (Fla.) College, $50,000 from Andrew Carnegie.

Yale University, $10,000 by the will of the late Walter D. Pitkins; $5,000 by the will of Mary P. Eakin.

APPOINTMENTS.

Carlos Ameghino, head of the division of paleontology, geology and anthropology in the National Museum at Buenos Aires.— Dr. Rufus M.

Bagg, professor of mineralogy and geology in the New Mexico Mining School.— Charles J. Brand, assistant curator of botany in the Field Columbian Museum.— Dr. E. Bresslau, docent for zoölogy in the University at Strassburg.— William S. Bullard, assistant in zoölogy in the University of Illinois.— Dr. S. M. Coulter, assistant professor of botany in Washington University.— M. Danniel, professor of agricultural botany at Rennes.— Dr. A. F. Dickson, professor of anatony in the college at Dublin.— Dr. J. E. Duerden, acting assistant professor of zoölogy in the University of Michigan.— Miss Ida Evans, instructor in biology in Rockwood College.— Dr. A. C. Eycleshymer, director of the anatomical department of the University of St. Louis.— Nevin M. Fenneman, assistant professor of geology in the University of Wisconsin.— Dr. Hans Fitting, docent of botany in the University at Tübingen.— Russell D. George of Iowa University, professor of geology in the University of Colorado.— Dr. Carl Wilhelm Genthe, assistant professor of Natural History in Trinity College.— Gay M. Hamilton, instructor in geology in the New Mexico School of Mines.— Dr. H. Spencer Harrison, demonstrator of biology in University College, Cardiff.— Emery R. Hayhurst, assistant in physiology in the University of Illinois.— Dr. Ludwig Hecke, professor extraordinary of plant diseases in the Vienna Agricultural School.— Dr. William A. Hilton, assistant in histology and embryology at Cornell University.— Dr. A. Hrdlicka, assistant curator in the anthropological division of the U. S. National Museum.— Dr. B. F. Kingsbury, assistant professor of embryology in Cornell University.— C. K. Leith, assistant professor of structural and economic geology in the University of Wisconsin.— Dr. A. G. Leonard, state geologist of North Dakota.— Dr. J. G. McCarthy, assistant professor of anatomy at McGill University.— Dr. J. J. R. McLeod, professor of physiology in the Western Reserve University.— Dr. Alphonse G. Malaquin, associate professor of zoölogy in Lille.— Dr. Page May, lecturer on the physiology of the nervous system at University College, London.— Dr. T. H. Montgomery, Jr., professor of zoölogy in the University of Texas.— Dr. J. P. Murlin, instructor in physiology in University and Bellevue Hospital Medical College.— Geo. W. Partridge, assistant in histology and embryology at Cornell University.— Amos W. Peters, instructor in zoölogy in the University of Illinois.— Dr. Joseph Felix Pompeckj, professor extraordinary of paleontology in the University at Munich.— Dr. Raymond H. Pond, professor of botany and pharmacognosy in North Western University.— Dr. C. W. Prentiss, instructor in biology in Western Reserve University.— Howard S. Reed, instructor in botany in the University of Wisconsin.— Dr. John L. Sheldon, professor of bacteriology in the University of West Virginia.— Dr. Sievers, professor of geography in the University at Giessen.— Dr. J. Rollin Slonaker, assistant professor of neurology in the Leland Stanford University.— Ralph E. Smith, professor of botany in the University of California.— Dr. Johannes Sobotta, professor extraordinary of anatomy in the University at Würzburg.— M. E. Stickney, instructor

in botany Denison University.— Michael X. Sullivan, instructor in chemical physiology in Brown University.— Carl B. Tames, instructor in biology in Western Reserve University.— Dr. Johannes Thiele, custodian of the zoölogical museum of the University of Berlin.— Henry L. Ward, custodian of the Milwaukee Public Museum, for five years.— D. G. Winter, assistant in histology and embryology in Cornell University.

RETIREMENTS.

F. W. Cragin, from the chair of geology in Colorado College.— Sir James Hector, from the directorship of the Geological Survey of New Zealand.— W. W. Stockberger, from the position of instructor in botany in Denison University.

DEATHS.

Andeas Allescher, mycologist, in Munich, April 10, aged 75.— William Talbot Aviline, connected with the British Geographical Survey for many years, May 12, aged 81.— Clarence Bartlett, Director of the Zoological gardens in London.— Dr. J. Blum, zoologist, in Frankfurt a. M., April 24, aged 70.— Luigi Bombicci, professor of mineralogy in the University at Bologna, May 17, aged 70.— Paul du Chaillu, African Explorer, in St. Petersburg, April 30, aged 68.— Dr. A. H. Chester professor of chemistry and mineralogy in Rutgers College, April 13, aged 60.— François Crépin, director of the botanical garden at Brussels.— Charles Darrah, student of cactaceæ, in Heaton, England.— Leonardo Fea, entomologist and assistant in the Civic museum of Genoa, in Turin, Apr. 29.— Dr. Edmund von Fellenburg von Bonstetten, geologist in Bern, May 10, 1902, aged 64.— Dr. Sigismund Fuchs, professor of physiology in the Agricultural School at Vienna, July 13.— Dr. Augustine Gattinger, student of the local flora, at Nashville, Tenn., July 18, aged 78.— Dr. Carl Gegenbaur, the eminent anatomist and professor of anatomy in the University at Heidelberg, June 14, aged 77.— Josef Haberhauĕr, student of Coleoptera, in Slivno, Bulgaria.— Prof. Karl Hausknecht, botanist, at Weimar, July 7.— Wilhelm von Hedemann, student of microlepidoptera, in Oberlössnitz near Dresden.— John F. Hicks, botanist, at Wooster, Ohio, June 1.— Dr. C. K. Hoffmann, professor of zoölogy in the University at Haarlem, July 28, aged 62.— Dr. Dirk Huizinga, former professor of physiology in the University at Groningen, in the Hague, May 15, aged 63.— Prof. Henry Griswald Jesup, for many years professor of botany at Dartmouth College, July 16, aged 77.— Felix Karrer, geologist and secretary of the scientific club of Vienna, April 19, aged 78.— Dr. A. Kaufmann, student of Ostracoda, in Basel, in March.— Dr. W. C. Knight, professor of geology in the University of Wyoming, July 8.— Dr. Nickolaus Alexis Kubilin, geologist and former director of the

Department of Mines of Russia, in St. Petersburg, April 23, aged 72.—
Prof. J. V. B. Laborde, director of the physiological Laboratory of the
Faculty of Medicine in Paris, April 8, aged 72.— J. Peter Lesley,
for many years geologist of the State of Pennsylvania, at Milton, Mass.,
June 1, aged 83.— Rev. Thomas Ansell Marshall, student of Hymenoptera,
at Ojaccio, Corsica, April 11.— Dr. Frederick V. August Meinert, long the
editor of the "Entomologiske Meddelelser," in Copenhagen, Mar. 3, aged
70.— Dr. Emmanuel Munk, professor extraordinary of physiology in the
University at Berlin, August 1, aged 51.— Dr. C. L. J. X. de la Vullée
Poussin, professor of mineralogy in the University at Louvain, Mar. 15,
aged 76.— Mr. Renard, professor of mineralogy in the University of Genth,
aged 60 years.— Heinrich, Baron Schilling von Canstatt, entomologist, in
Friedrichshafen, May 18, aged 53.— Dr. Heinrich Schurtz, ethnologist and
assistant in the city museum in Bremen, May 4.— Dr. Max Westermaier,
professor of botany in the University of Fribourg, Switzerland, May 1,
aged 50.

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